ARPA/ONR Medical Ultrasonic Imaging Technology Workshop

Presentation Abstracts

Advanced Research Projects Agency

Office of Naval Research

Lansdowne, Virginia

January 24-26, 1995

Please Expedite 11/14 OCP

Have a request for this document

OFFICE OF THE UNDER SECRETARY OF DEFENSE (ACQUISITION & TECHNOLOGY)
DEFENSE TECHNICAL INFORMATION CENTER
CAMERON STATION
ALEXANDRIA, VIRGINIA 22304-6145

IN REPLY REFER TO DTIC-OCP (703) 274-6847 (DSN) 284-6847
AQ M95-3713

SUBJECT: Request for Scientific and Technical Report

TO:

1. We have been unable to locate the report referenced below in the Defense Technical Information Center Collection. In accordance with DoDD 3200.12 "DoD Scientific and Technical Information Program" the Defense Technical Information Center is to receive two copies of the Technical Report cited below.

2. All copies of the report must be suitable for reproduction including a clearly marked distribution statement as described in DoDD 5230.24. (See reverse side for categories of distribution statement.) A clearly marked loan copy suitable for reproduction is acceptable.

3. If for any reason you cannot furnish the report, please return the copy of this letter annotating your reason on the reverse side.

4. A mailing label for shipping the reports and a DTIC Form 50 to obtain the AD number after processing are enclosed.

2 Encl
1. Mailing Label
2. DTIC Form 50

Chief, Programs
Management Branch

TITLE: ARPA/ONR Medical Ultrasonic Imaging Technology Workshop Jan 24-26, 1995

19951205 180

DTIC FL-88, MAR 94

PLEASE CHECK THE APPROPRIATE BLOCK BELOW:

- [x] __1__ copies are being forwarded. Indicate whether Statement A, B, C, D, E, F, or X applies.

- [x] DISTRIBUTION STATEMENT A: Per Jon Coy ARPA Library
  APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED
- [ ] DISTRIBUTION STATEMENT B:
  DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES ONLY; (Indicate Reason and Date). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).
- [ ] DISTRIBUTION STATEMENT C:
  DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND THEIR CONTRACTORS; (Indicate Reason and Date). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).
- [ ] DISTRIBUTION STATEMENT D:
  DISTRIBUTION AUTHORIZED TO DOD AND U.S. DOD CONTRACTORS ONLY; (Indicate Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office).
- [ ] DISTRIBUTION STATEMENT E:
  DISTRIBUTION AUTHORIZED TO DOD COMPONENTS ONLY; (Indicate Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office).
- [ ] DISTRIBUTION STATEMENT F:
  FURTHER DISSEMINATION ONLY AS DIRECTED BY (Indicate Controlling DoD Office and Date) or HIGHER DOD AUTHORITY.
- [ ] DISTRIBUTION STATEMENT X:
  DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND PRIVATE INDIVIDUALS OR ENTERPRISES ELIGIBLE TO OBTAIN EXPORT-CONTROLLED TECHNICAL DATA IN ACCORDANCE WITH DOD DIRECTIVE 5230.25, WITHHOLDING OF UNCLASSIFIED TECHNICAL DATA FROM PUBLIC DISCLOSURE, 6 Nov 1984 (Indicate date of determination). CONTROLLING DOD OFFICE IS (Indicate Controlling DoD Office).

- [ ] This document was previously forwarded to DTIC on ____________ (date) and the AD number is ______________.

- [ ] In accordance with the provisions of DoD instructions, the document requested is not supplied because:

- [ ] It is TOP SECRET.

- [ ] It is excepted in accordance with DoD instructions pertaining to communications and electronic intelligence.

- [ ] It is a registered publication.

- [ ] It is a contract or grant proposal, or an order.

- [ ] It will be published at a later date. (Enter approximate date, if known.)

- [ ] Other. (Give Reason.)

Call Sue Lewis @ 696-2210 for a distribution

Authorized Signature Date

Print or Typed Name

Telephone Number

Agenda

 Final Agenda

ARPA/ONR Medical Ultrasonic Imaging Technology Workshop
24-26 January 1995

Tuesday 24 January 1995

0800-0820 Perspectives on Planned Defense Programs in Medical Ultrasonics
F. W. Patten, I. Skurnick, and W. A. Smith* ARPA and *ONR

0825-0845 Basic Problems in Aberration Correction
B. D. Steinberg, University of Pennsylvania

0850-0910 Two-Step Aberration Correction
M. O'Donnell, S. Krishnan, and K. W. Rigby* University of Michigan and * General Electric CRD

0915-0935 DISCUSSION

0935-0955 COFFEE BREAK

0955-1015 Phase Aberrations in Quantitative Ultrasonic Imaging
J. H. Rose, M. R. Holland* M. Bilgen, K. W. Hollman* S. A. Wickline* and J. G. Miller*
Iowa State University, and * Washington University

1020-1040 Quantitative Three Dimensional Imaging in Ultrasound
A. J. Devaney, Northeastern University

1045-1105 Waveform Aberrations in an Animal Model
B. S. Robinson, A. Shmulewitz, T. M. Burke, and J. E. Powers, ATL

1110-1130 DISCUSSION

1130-1230 LUNCH

1230-1250 Topics in Ultrasonic Imaging
D. E. Robinson, Y. Li, D. A. Carpenter, and G. Kossoff, CSIRO

1255-1315 Three Dimensional Cardiac Ultrasound — The Next Generation
R. W. Martin, and F. H. Sheehan, University of Washington

1320-1340 Real-Time Ultrasonic Tomography
M. S. Good, G. J. Posakony, S. R. Doctor, R. J. Littlefield, and M. A. Lind, Pacific Northwest Lab

1345-1405 Time for a New Paradigm for Ultrasonic Medical Imaging
D. Vilkomerson, EchoCath

1410-1435 DISCUSSION

1435-1455 COFFEE BREAK

1455-1515 Volumetric Ultrasonic Assays of Tissue Microstructure and Blood Flow
F. L. Lizzi, E. J. Feleppa, and K. W. Ferrara, Riverside Research Institute

1520-1540 Multiorgan Diagnostic Screening and Minimally Invasive Therapy with Portable Ultrasound
C. Oakley, L. J. Busse, and D. R. Dietz, Tetrad

 Final Agenda

1545-1605 Hand-Held Ultrasound
M. O'Donnell and M. Karaman, University of Michigan

1610-1630 High Definition Ultrasonic Imaging
I. G. Stiglitz, S. R. Broadstone, and G. R. Benitz, MIT Lincoln Laboratory

1635-1700 DISCUSSION

Wednesday 25 January 1995

0800-0820 Factors Affecting the Accuracy and Stability of Adaptive Imaging Using Two-Dimensional Arrays
G. E. Trahey, Duke University

0825-0845 Two-Dimensional Arrays for Medical Ultrasound Imaging
S. W. Smith, Duke University

0850-0910 A Novel Ultrasound Three-Dimensional Approach
A. Nicoli, N. Butler, T. White, and M. Lasser, Loral Infrared Imaging Systems

0915-0935 DISCUSSION

0935-0955 COFFEE BREAK

0955-1015 "Non-Invasive Surgery" Applied to the Control of Hemorrhage from Blunt Trauma
Edward C. Driscoll, Jr., FOCUS Surgery

1020-1040 Development of Very High Frequency Ultrasonic Imaging Systems
J. P. Jones, University of California Irvine

1045-1105 High-Frequency Acoustic Imaging for Early Detection of Skin Breakdown
J. E. Sanders, R. A. Roy, and B. S. Goldstein, University of Washington

1110-1130 DISCUSSION

1130-1230 LUNCH

1230-1250 Assessment of Advanced Laser Ultrasonic Technology
R. M. Grills and A. J. Patrick* Ultra Image International and * Textron Defense Systems

1255-1315 Functional Ultrasound
R. W. Gill, L. S. Wilson, T. Loupas, and G. Kossoff, CSIRO

1320-1340 The Use of Diagnostic Ultrasound for Radiolucent Shrapnel Detection and Wound Assessment
L. A. Crum and R. W. Martin, University of Washington

1345-1405 Elastography: Imaging of Tissue Elastic Properties In Vivo
J. Ophir, I. Cepedes, N. Maklad, B. Garra* and H. Ponnekanti
University of Texas and * Georgetown University

1410-1435 DISCUSSION

1435-1455 COFFEE BREAK

 Final Agenda

1455-1515 The New Theory of Sonoelasticity
K. J. Parker, L. Gao, S. K. Alam, D. J. Rubens and R. Lerner, University of Rochester

1520-1540 Clinical Uses of Sonoelasticity
D. J. Rubens, K. J. Parker, L. Gao, S. K. Alam, and R. Lerner, University of Rochester

1545-1605 A New Approach to Remote Ultrasonic Evaluation of Viscoelastic Properties of Tissues for Diagnostics and Healing Monitoring
A. P. Sarvazyan, Rutgers University

1610-1630 Medical Ultrasound Image Improvement Opportunities: (1) Improved Battlefield Imaging through Correction of Tissue Induced Aberrations; (2) Improved Breast Cancer Detection through Inverse Scattering
S. Johnson, TechniScan

1635-1700 DISCUSSION

Thursday 26 January 1995

0800-0820 Sattelite Telemedicine
B. K. Stewart and S. J. Carter, University of Washington

0825-0845 Net-Shape Piezocomposite Transducers for Ultrasonic Imaging Arrays
L. J. Bowen and R. L. Gentilman, Materials Systems

0850-0910 Ultrasonic Transducer/Array Research at Penn State
K. K. Shung, W. Cao, W. J. Hughes, J. Meilstrup, T. Shrout, W. J. Thompson, Jr., and R. Tutweiler
Pennsylvania State University

0915-0935 Science and Technology Based Developments at NRL Related to Medical Ultrasonic Imaging
H. H. Chaskelis, Naval Research Laboratory

0940-1005 DISCUSSION

1005-1025 COFFEE BREAK

1025-1045 Full Bandwidth Utilization with Digital Beam Forming
J. E. Powers, R. R. Entrekin, and J. Souquet, ATL

1050-1110 High-Speed, Low-Power Signal Processors for Portable Medical Ultrasound
A. M. Chiang, TeraTech Corporation

1115-1135 Digital Technology for Medical Ultrasound Imaging
M. N. Witlin and M. E. Haran, Loral Federal Systems

1140-1200 DISCUSSION

1200-1300 LUNCH

Participants

(by name)

WORKSHOP REGISTRANTS

(listed in alphabetical order by participant)

Dr. Robert Asaro
Trans-Science Corporation
7777 Fay Avenue
Suite 112
La Jolla, California 92037
telephone: (619) 459-1240 email/misc.
fax: (619) 459-0210

Dr. Kenneth Bates
Applied Concepts
575 Stonegate Street
Eugene, Oregon 97401
telephone: (503) 686 1827 email/misc. general
fax: (503) 343-7861

Dr. Kirk Beach
University of Washington
Surgery, RF-25
Seattle, Washington
telephone: (206) 543-3827 email/misc.
fax: (206) 543-8136

Dr. John U. Beusch
MIT Lincoln Laboratory
Group 93
244 Wood Street
Lexington, MA 02173-9108
telephone: 617-981-7932 email/misc.
fax: 617-981-0993

Dr. V. Bheemineni
MRA Laboratories, Inc.
96 Marshall Street
North Adams, Massachusettes
telephone: (413) 664-4524 email/misc.
fax: (413) 663-5535

Dr. Leslie J. Bowen
Material Systems Incorporated
521 Great Road
Littleton, MA 01460
telephone: (508) 486-0404 email/misc.
fax: (508) 486-0706 fax

Dr. Keith Bridger
Martin Marietta Laboratories
1450 South Rolling Road
Baltimore, Maryland
telephone: (410) 204-2235 email/misc.
fax: (410) 204-

Dr. Steven Broadstone
MIT Lincoln Labs
Advanced Techniques Group, MS D351
244 Wood Street
Lexington, Massachusetts
telephone: (617) 981-7440 email/misc. srb@ll.mit.edu
fax: (617) 981 0300

Alice A. Burgess
Strategic Analysis, Inc.
4001 N. Fairfax Drive
Suite 175
Arlington, VA 22203
telephone: (703) 527-5410 email/misc.
fax: (703) 527-5445

Dr. Neil Butler
Loral Infra Red Imaging Systems
2 Forbes Road
Lexington, Massachusetts
telephone: (617) 863- email/misc.
fax: (617) 863-

Prof. W. Cao
Pennsylvania State University
Materials Research Laboratory
164 MRL
University Park, Pennsylvania
telephone: (814) 865-4101 email/misc.
fax: (814) 865-2326

Dr. Patrick Castelaz
Loma Linda University Medical Center
National Medical Technology Test Bed
5050 Via Donaldo
Yorba Linda, CA 92686
telephone: (714) 779-6339 email/misc.
fax: (714) 779-5653

Dr. Henry H. Chaskelis
Naval Research Laboratory
Mechanics of Materials Branch, Code 6380
4555 Overlook Avenue, SW
Washington, DC 20375-5320
telephone: (202) 767-3613 email/misc. henry@sh.nrl.navy.mil
fax: (202) 767-9181

Dr. Alice Chiang
Teratech Corporation
President
223 Middlesex Turnpike
Burlington, MA 01803
telephone: (617) 891-4988 or email/misc.
fax: (617) 270-6828

WORKSHOP REGISTRANTS

(listed in alphabetical order by participant)

Dr. Scott S. Corbett
Microsound Systems
11720 S.W. 28th Place
Portland, OR 97219

telephone: (503) 246-5403
fax: (503) 246-5187
email/misc.

Prof. John M.Cornwall
UCLA
Department of Physics
Los Angeles, CA 90095

telephone: (310) 825-3162
fax: (310) 206-5668
email/misc.

Dr. Lawrence A. Crum
University of Washington
Applied Physics Laboratory
1013 North East 40th Street
Seattle, Washington

telephone: (206) 685-8622
fax: (206) 685-8621 fax
email/misc. *(206) 543-1300 general*
lac@anchor.apl.washingto

Dr. Charles S. Desilets
UltraSound Solutions
1215 Highland Drive
Edmonds, Washington

telephone: (206) 775-4724
fax. (206) 775-4724 fax
email/misc. *(206) 672 2784 home*

Prof. Anthony J. Devaney
Northeastern University
Department of Electrical Engineering
Huntington Avenue
Boston, Massachusetts

telephone: (617) 437 5284
fax: fax
email/misc. *general*

Dr. Fred M. Dickey
Sandia National Laboratories
Optical Systems & Imaging Processing
MS 0843
Albuquerque, NM 87185-0843

telephone: (505) 844-9660
fax: (505) 844-4157
email/misc.

Dr. Dennis Dietz
Tetrad Corporation
Systems Development
357 Inverness Drive S.
Englewood, Colorado 80112

telephone: (303) 754-2320
fax: (303)
email/misc.

Dr. Edward Driscoll, Jr.
Focus Surgery
225 Hammond Avenue
Fremont, CA 94539

telephone: (510) 354-3702
fax: (510) 354-1544
email/misc.

Brenda Fischetti
Strategic Analysis, Inc.
4001 N. Fairfax Drive
Suite 175
Arlington, VA 22203

telephone: (703) 527-5410
fax: (703) 527-5445
email/misc.

Jenny C. Fung
Systems Planning Corporation
1429 N. Quincy Street
Arlington, VA 22207

telephone: (703) 696-2265
fax: (703) 696-2201
email/misc. *jfung@dso.snap.org*

Dr. Robert W. Gill
Ultrasonics Laboratory
Division of Radiophysics, CSIRO
126 Creville St.
Chatswood, NSW 2067,

telephone: (61-2) 412-6006
fax: (61-2) 411-5708
email/misc.

Dr. Morris Good
Battelle, Pacific Northwest Laboratories
Automation and Measurement Sciences Department
Battelle Boulevard
Richland, Washington

telephone: (509) 375-2529
fax: (509)
email/misc.

Prof. James F. Greenleaf
Mayo Clinic
Biodynamics Research Unit
200 First Street, SW
Rochester, Minnesota 55905

telephone: (507) 284-8496
fax: (507) 284-1632 fax
email/misc. *(507) 284-2811*

Robert H. Grills
Ultra Image International
Marketing and Business Development
Two Shaw's Cove, Suite 101
New London, CT 06320

telephone: (203) 442-0100
fax: (203) 442-2389
email/misc.

WORKSHOP REGISTRANTS

(listed in alphabetical order by participant)

Dr. Michael E. Haran
Loral Federal Systems Division
Systems Integration Business Development
9500 Godwin Drive - 120/025
Manassas, Virginia 22110
telephone: (703) 367-1397 email/misc.
fax: (703) 367-6319

Dr. G.A. Hegemier
Trans-Science Corporation
7777 Fay Avenue
Suite 112
La Jolla, California 92037
telephone: (619) 459-1240 email/misc.
fax: (619) 459-0210

Dr. Mark R. Holland
Washington University
Physics Department, Lab for Ultrasonics
Box 1105, One Brookings Drive
St. Louis, Missouri 63130
telephone: (314) 935-6402 email/misc. *(314) 725 8732 home*
fax: (314) 935-5868 fax *jgm@wuphys.wustl.edu*

Dr. W. Jack Hughes
Pennsylvania State University
ARL
Box 30
State College, PA 16804
telephone: (814) 865-1721 email/misc.
fax: (814) 863-7841

Dr. Donald Jenkins
ARPA/DSO
Defense Healthcare Technologies
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-2240 email/misc.
fax: (703) 696-2203

Dr. Bruce Johnson
Naval EOD Technology Division
R&D Division, Code 50A15
2008 Stump Neck Road
Indian head, MD 20640-5070
telephone: (301) 743-6850/248 email/misc.
fax: (301) 743-6947

Dr. Steven A. Johnson
TechniScan, Inc.
958 West LeVoy Drive
#200
Salt Lake City, Utah 84123
telephone: (801) 266-7700 email/misc.
fax: (801) 261-1182

Prof. Joie Pierce Jones
University of California at Irvine
College of Medicine
Department of Radiological Sciences, RM B140
Irvine, CA 92717
telephone: (714) 824-6147 email/misc. *jpjones@uci.edu*
fax: (714) 824-6532

LCDR Shaun Jones, M.D.
ARPA/DSO
Defense Healthcare Technologies
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-4427 email/misc.
fax:

Dr. Marvin E. Lasser
Marvin E. Lasser, Inc.
2092 Gaither Road
Suite 220F
Rockville, Maryland 20850
telephone: (301) 208-6775 email/misc. *marlasser@aol.com*
fax: (301) 208-8227

Dr. Michael A. Lind
Battelle, Pacific Northwest Laboratory
Office of Technology Partnerships,
P.O. Box 999; MSIN: K7-02
Richland, Washington
telephone: (509) 375-4405 email/misc.
fax: (509) 275-6499

Dr. Thomas E. Linnenbrink
Q-Dot Incorporated
1069 Elkton Drive
Colorado Springs, Colorado
telephone: (719) 590 1112 email/misc. *general*
fax: (719) 590 1125 fax

Dr. R.J. Littlefield
Battelle, Pacific Northwest Laboratories
Analytic Science and Engineering Department
P.O. Box 999
Richland, Washington
telephone: (509) 375-3927 email/misc.
fax: (509) 375-3641

Dr. Frederic L. Lizzi
Riverside Research Institute
330 West 42nd Street
New York, New York 10036
telephone: (212) 502-1774 email/misc. *(201) 567-1281 home*
fax: (212) 502-1729

WORKSHOP REGISTRANTS

(listed in alphabetical order by participant)

Dr. Akhilesh Maewal
Trans-Science Corporation
7777 Fay Avenue
Suite 112
La Jolla, California 92037
telephone: (619) 459-1240 email/misc.
fax: (619) 459-0210

Prof. Roy Martin
University of Washington
Anesthesiology & Bioengineering
Room RR-450, Health Science Bldg, MS RN-10
Seattle, Washington
telephone: (206) 685-1883 email/misc. *rmartin@car.u.washington.edu*
fax: (206) 685-3079 fax

David Nelson
Harvard University
Department of Physics
Cambridge, MA 02138
telephone: (617) 495-4331 email/misc.
fax: (617) 495-0416

Dr. Leo Neumann
Analogic Corp.
Vice President of R&D
8 Centennial Drive
Peabody, Massachusetts
telephone: (508) 977-3000 ext email/misc. *lneumann@analogic.com*
fax: (508) 977-6811

Dr. Anthony Nicoli
Loral Infra Red Imaging Systems
2 Forbes Road
Lexington, Massachusetts
telephone: (617) 863-3119 email/misc.
fax: (617) 863-4249

Dr. Sharbel Noujaim
GE Medical Systems
Ultrasound Advanced Technology
P.O. Box 414 EA-56
Milwaukee, WI 53201
telephone: (414) 647-7728 email/misc. *ms11677@msbg.med.ge.com*
fax: (414) 647-4117/4090

Prof. Matthew O'Donnell
University of Michigan
Electrical Engineering and Computer Science Department
Biomedical Ultrasonics Laboratory
Ann Arbor, Michigan
telephone: (313) 764-8589 email/misc. *(313) 763-5488*
fax: (313) 936-1905 fax

Dr. Clyde G. Oakley
Tetrad Corporation
Systems Development
357 Inverness Dr. S.
Englewood, Colorado 80112
telephone: email/misc. *(303)*
fax: (303) 754-2315

Prof. Jonathan Ophir
University of Texas Medical School
Dept of Radiology, MSB 2130
6431 Fannin
Houton, TX 77030
telephone: (713) 792-5842 email/misc. *jophir@msrad3.med.uth.tmc.edu*
fax: (713) 792-5645

Mr. John T. Oxaal
3D Ultrasound Incorporated
302 Pettigrew Street
Suite 307
Durham, North Carolina
telephone: email/misc. *(919) 682 0991 fax*
fax: (919) 688 0112

Prof. Kevin J. Parker
University of Rochester
Department of Electrical Engineering
518 Computer Studies Building
Rochester, New York 14627
telephone: (716) 275-3294 email/misc. *(716) 271-8433 home*
fax: (716) 275-2073

Alexander J. Patrick, Jr.
Textron Defense Systems
Energy Technology
2385 Revere Beach Parkway
Everett, MA 02149
telephone: (617) 381-4173 email/misc. *none*
fax: (617) 381-4160

Dr. Francis W. Patten
ARPA/DSO
Materials Science
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-2285 email/misc.
fax: (703) 696-2201

Dr. Jeffrey Powers
Advanced Technology Laboratories
22100 Bothel Highway South East
Post Office Box 3003
Bothell, Washington
telephone: (206) 487-7126 email/misc. *jpower@atl.com*
fax: (206) 486-5220

WORKSHOP REGISTRANTS

(listed in alphabetical order by participant)

Dr. Wayne Rigby
GE Corporate R&D
1 River Road
KWC 434
Niskyona, NY 12309
telephone: (518) 387-7705
fax: (518) 387-5975
email/misc.

Dr. David E. Robinson
Ultrasonics Laboratory
Division of Radiophysics, CSIRO
126 Creville St.
Chatswood, NSW 2067,
telephone: (61-2) 412-6003
fax: (61-2) 411-5708
email/misc.

Dr. James H. Rose
Iowa State University
Center for NDE
Ames, IA 50011
telephone: (515) 294-7537
fax: (515) 294-7771
email/misc.

Dr. Ronald A. Roy
University of Washington
Applied Physics Laboratory
1013 NE 40 Street
Seattle, WA 98105
telephone: (206) 543-7721
fax: (206) 543-6785
email/misc. rroy@apl.washington.edu

Dr. Joan Sanders
University of Washington
Department of Bioengineering
MS WD-12
Seattle, WA 98195
telephone: (206) 685-8296
fax: (206) 543-6124
email/misc.

Prof. Armen Sarvazyan
Rutgers University
Department of Chemistry
Busch Campus, P.O. Box 939
Piscataway, New Jersey
telephone: (908) 445-4792
fax: (908) 445-5312
email/misc. Email sarvazyan@zodiac.rutgers

COL Richard Satava, M.D., USA
ARPA/DSO
Defense Healthcare Technologies
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-2265
fax: (703) 696-2201
email/misc.

Dr. Mark E. Schafer
Sonic Technologies, Inc.
2935 Byberry Road
Hatsboro, Pennsylvania
telephone: (215) 957 2352
fax: (215) 957 2355
email/misc. (215) 277 5652 home

Dr. Rainer Schmitt
Fraunhofer Institut Biomedizinische Technik
Department of Ultrasound
Ensheimer Strasse 48
D-66386 St. Ingbert, Germany
telephone: 49+6894 980 200
fax: 49+6894 980 400 fax
email/misc.

Dr. Chandra M. Sehgal
University of Pennsylvania
Department of Radiology
341 Stemmler Hall 36th & Hamilton Walk
Philadelphia, Pennsylvania
telephone: (215) 349-5461
fax: (215) 349-5115
email/misc. general

Dr. Florence Sheehan
University of Washington
MS RG22
HSB RR616
Seattle, Washington
telephone: (206) 543-4535
fax: (206) 685-9394
email/misc.

Professor K. Kirk Shung
Pennsylvania State University
Bioengineering Program
231 Hallowell Building
University Park, Pennsylvania
telephone: (814) 865-1407
fax: (814) 863-0490
email/misc.

COL John Silva, M.D., USAF
ARPA/SSTO
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-2221
fax:
email/misc.

Dr. Ira D. Skurnick
ARPA/DSO
Defense Healthcare Technologies
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-2286
fax: (703) 696-2201
email/misc.

WORKSHOP REGISTRANTS

(listed in alphabetical order by participant)

Dr. Michael Slayton
Guided Therapy Systems, Inc.
1833 West Main Street
128
Mesa, Arizona 85201
telephone: (602) 649-4399 email/misc. *alb@crl.com*
fax: (602) 649-1605

Prof. Stephen W. Smith
Duke University
Department of Biomedical Engineering
136 Engineering Building
Durham, North Carolina
telephone: (919) 660-5160 office email/misc. *(919) 660-5131 message*
fax: (919) 684-4488 fax

Dr. Wallace Smith
Office of Naval Research
Materials Division, ONR 332
800 N. Quincy Street, Room 502
Arlington, VA 22217-5660
telephone: (703) 696-0284 email/misc.
fax: (703) 696-0934

Mr. Scott Smith
GE Corporate R&D
Ultrasound Program
P.O. Box 8
Schenectady, NY 12301
telephone: (518) 387-5996 email/misc.
fax: (518) 387-5975

Dr. Bernard D. Steinberg
University of Pennsylvania
Valley Forge Research Center
200 S. 33rd Street
Philadelphia, Pennsylvania
telephone: (215) 898-6352 email/misc.
fax: (215) 573-2068

Dr. Brent Stewart
University of Washington
Department of Radiology
MS RC-05
Seattle, WA 98195
telephone: (206) 548-6252 email/misc. *bstewart@u.washington.edu*
fax: (206) 543-3495

Dr. Irvin G. Stiglitz
MIT Lincoln Labs
Advanced Techniques Group
244 Wood Street
Lexington, Massachusetts
telephone: (617) 981-7440 email/misc.
fax: (617) 981 0300

Dr. Kai Thomenius
ATL Interspec Incorporated
110 West Butler Avenue
Ambler, Pennsylvania
telephone: (215) 540 9190/1719 email/misc.
fax: (215) 540 9711 fax

Prof. Gregg E. Trahey
Duke University
Department of Biomedical Engineering
Post Office Box 90281
Durham, North Carolina
telephone: (919) 660-5169 email/misc. *general*
fax: (919) 684-4488 fax

Dr. Richard L. Tutwiler
Pennsylvania State University
ARL
Box 30
State College, PA 16804
telephone: (814) 863-2188 email/misc.
fax: (814) 863-7841

Dr. David Vilkomerson
EchoCath Incorporated
Post Office Box 7224
Princeton, New Jersey
telephone: (609) 987 8400 ext 12 email/misc. *general*
fax: (609) 987 1019 fax

Prof. Olaf T. von Ramm
Duke University
Center for Emerging Cardiovascular Tech.
B237 LSRC, Box 90295
Durham, North Carolina
telephone: (919) 660-5137 email/misc. *(919) 684-6398 hospital*
fax: (919) 684-8886 *(919) 563-4426 home*

Dr. Timothy E. White
Loral Infra Red Imaging Systems
2 Forbes Road
Lexington, Massachusetts
telephone: (617) 863 3119 email/misc. *tim_white@liris.loral.com*
fax: (617) 863 4249 fax

Dr. Richard M. Williams
Martin Marietta
Electronics Park Plant
Bldg 7, Room 349
Syracuse, New York
telephone: (315) 456-1418 email/misc.
fax: (315) 456-1430

WORKSHOP REGISTRANTS

(listed in alphabetical order by participant)

Dr. Stephen R. Winzer
Martin Marietta
1450 South Rolling Road
Baltimore, Maryland

telephone: (410) 204-2415 email/misc. *general*
fax: (410) 204 2100

Dr. Michael Witlin
Loral Federal Systems Division
Manassas Laboratory
9500 Godwin Drive
Manassas, Virginia 22110
telephone: (703) 367-2946 email/misc. *witlin@lfs.loral.com*
fax: (703) 367-5067

Participants

(by organization)

WORKSHOP REGISTRANTS

(listed in order of organization)

Mr. John T. Oxaal
3D Ultrasound Incorporated
302 Pettigrew Street
Suite 307
Durham, North Carolina
telephone:
fax: (919) 688 0112
email/misc. *(919) 682 0991 fax*

Dr. Jeffrey Powers
Advanced Technology Laboratories
22100 Bothel Highway South East
Post Office Box 3003
Bothell, Washington
telephone: (206) 487-7126
fax: (206) 486-5220
email/misc. *jpower@atl.com*

Dr. Leo Neumann
Analogic Corp.
Vice President of R&D
8 Centennial Drive
Peabody, Massachusetts
telephone: (508) 977-3000 ext
fax: (508) 977-6811
email/misc. *lneumann@analogic.com*

Dr. Kenneth Bates
Applied Concepts
575 Stonegate Street
Eugene, Oregon 97401
telephone: (503) 686 1827
fax: (503) 343-7861
email/misc. *general*

Dr. Donald Jenkins
ARPA/DSO
Defense Healthcare Technologies
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-2240
fax: (703) 696-2203
email/misc.

LCDR Shaun Jones, M.D.
ARPA/DSO
Defense Healthcare Technologies
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-4427
fax:
email/misc.

Dr. Francis W. Patten
ARPA/DSO
Materials Science
3701 N. Fairfax Drive
Arlington, Virginia
telephone. (703) 696-2285
fax: (703) 696-2201
email/misc.

COL Richard Satava, M.D., USA
ARPA/DSO
Defense Healthcare Technologies
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-2265
fax: (703) 696-2201
email/misc.

Dr. Ira D. Skurnick
ARPA/DSO
Defense Healthcare Technologies
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-2286
fax: (703) 696-2201
email/misc.

COL John Silva, M.D., USAF
ARPA/SSTO
3701 N. Fairfax Drive
Arlington, Virginia
telephone: (703) 696-2221
fax:
email/misc.

Dr. Kai Thomenius
ATL Interspec Incorporated
110 West Butler Avenue
Ambler, Pennsylvania
telephone: (215) 540 9190/1719
fax: (215) 540 9711 fax
email/misc.

Dr. Morris Good
Battelle, Pacific Northwest Laboratories
Automation and Measurement Sciences Department
Battelle Boulevard
Richland, Washington
telephone: (509) 375-2529
fax: (509)
email/misc.

Dr. R.J. Littlefield
Battelle, Pacific Northwest Laboratories
Analytic Science and Engineering Department
P.O. Box 999
Richland, Washington
telephone: (509) 375-3927
fax: (509) 375-3641
email/misc.

Dr. Michael A. Lind
Battelle, Pacific Northwest Laboratory
Office of Technology Partnerships,
P.O. Box 999; MSIN: K7-02
Richland, Washington
telephone: (509) 375-4405
fax: (509) 275-6499
email/misc.

WORKSHOP REGISTRANTS

(listed in order of organization)

Prof. Stephen W. Smith
Duke University
Department of Biomedical Engineering
136 Engineering Building
Durham, North Carolina
telephone: (919) 660-5160 office
fax: (919) 684-4488 fax
email/misc. *(919) 660-5131 message*

Mr. Scott Smith
GE Corporate R&D
Ultrasound Program
P.O. Box 8
Schenectady, NY 12301
telephone: (518) 387-5996
fax: (518) 387-5975
email/misc.

Prof. Gregg E. Trahey
Duke University
Department of Biomedical Engineering
Post Office Box 90281
Durham, North Carolina
telephone: (919) 660-5169
fax: (919) 684-4488 fax
email/misc. *general*

Dr. Sharbel Noujaim
GE Medical Systems
Ultrasound Advanced Technology
P.O. Box 414 EA-56
Milwaukee, WI 53201
telephone: (414) 647-7728
fax: (414) 647-4117/4090
email/misc. *ms11677@msbg.med.ge.c om*

Prof. Olaf T. von Ramm
Duke University
Center for Emerging Cardiovascular Tech.
B237 LSRC, Box 90295
Durham, North Carolina
telephone: (919) 660-5137
fax: (919) 684-8886
email/misc. *(919) 684-6398 hospital*
(919) 563-4426 home

Dr. Michael Slayton
Guided Therapy Systems, Inc.
1833 West Main Street
128
Mesa, Arizona 85201
telephone: (602) 649-4399
fax: (602) 649-1605
email/misc. *alb@crl.com*

Dr. David Vilkomerson
EchoCath Incorporated
Post Office Box 7224
Princeton, New Jersey
telephone: (609) 987 8400 ext 12
fax: (609) 987 1019 fax
email/misc. *general*

David Nelson
Harvard University
Department of Physics
Cambridge, MA 02138
telephone: (617) 495-4331
fax: (617) 495-0416
email/misc.

Dr. Edward Driscoll, Jr.
Focus Surgery
225 Hammond Avenue
Fremont, CA 94539
telephone: (510) 354-3702
fax: (510) 354-1544
email/misc.

Dr. James H. Rose
Iowa State University
Center for NDE
Ames, IA 50011
telephone: (515) 294-7537
fax: (515) 294-7771
email/misc.

Dr. Rainer Schmitt
Fraunhofer Institut Biomedizinische Technik
Department of Ultrasound
Ensheimer Strasse 48
D-66386 St. Ingbert, Germany
telephone: 49+6894 980 200
fax: 49+6894 980 400 fax
email/misc.

Dr. Patrick Castelaz
Loma Linda University Medical Center
National Medical Technology Test Bed
5050 Via Donaldo
Yorba Linda, CA 92686
telephone: (714) 779-6339
fax: (714) 779-5653
email/misc.

Dr. Wayne Rigby
GE Corporate R&D
1 River Road
KWC 434
Niskyona, NY 12309
telephone: (518) 387-7705
fax: (518) 387-5975
email/misc.

Dr. Michael E. Haran
Loral Federal Systems Division
Systems Integration Business Development
9500 Godwin Drive - 120/025
Manassas, Virginia 22110
telephone: (703) 367-1397
fax: (703) 367-6319
email/misc.

WORKSHOP REGISTRANTS

(listed in order of organization)

Dr. Michael Witlin
Loral Federal Systems Division
Manassas Laboratory
9500 Godwin Drive
Manassas, Virginia 22110
telephone: (703) 367-2946 email/misc. *witlin@lfs.loral.com*
fax: (703) 367-5067

Dr. Neil Butler
Loral Infra Red Imaging Systems
2 Forbes Road
Lexington, Massachusetts
telephone: (617) 863- email/misc.
fax: (617) 863-

Dr. Anthony Nicoli
Loral Infra Red Imaging Systems
2 Forbes Road
Lexington, Massachusetts
telephone: (617) 863-3119 email/misc.
fax: (617) 863-4249

Dr. Timothy E. White
Loral Infra Red Imaging Systems
2 Forbes Road
Lexington, Massachusetts
telephone: (617) 863 3119 email/misc. *tim_white@liris.loral.com*
fax: (617) 863 4249 fax

Dr. Richard M. Williams
Martin Marietta
Electronics Park Plant
Bldg 7, Room 349
Syracuse, New York
telephone: (315) 456-1418 email/misc.
fax: (315) 456-1430

Dr. Stephen R. Winzer
Martin Marietta
1450 South Rolling Road
Baltimore, Maryland
telephone: (410) 204-2415 email/misc. *general*
fax: (410) 204 2100

Dr. Keith Bridger
Martin Marietta Laboratories
1450 South Rolling Road
Baltimore, Maryland
telephone: (410) 204-2235 email/misc.
fax: (410) 204-

Dr. Marvin E. Lasser
Marvin E. Lasser, Inc.
2092 Gaither Road
Suite 220F
Rockville, Maryland 20850
telephone: (301) 208-6775 email/misc. *marlasser@aol.com*
fax: (301) 208-8227

Dr. Leslie J. Bowen
Material Systems Incorporated
521 Great Road
Littleton, MA 01460
telephone: (508) 486-0404 email/misc.
fax: (508) 486-0706 fax

Prof. James F. Greenleaf
Mayo Clinic
Biodynamics Research Unit
200 First Street, SW
Rochester, Minnesota 55905
telephone: (507) 284-8496 email/misc. *(507) 284-2811*
fax: (507) 284-1632 fax

Dr. Scott S. Corbett
Microsound Systems
11720 S.W. 28th Place
Portland, OR 97219
telephone: (503) 246-5403 email/misc.
fax: (503) 246-5187

Dr. John U. Beusch
MIT Lincoln Laboratory
Group 93
244 Wood Street
Lexington, MA 02173-9108
telephone: 617-981-7932 email/misc.
fax: 617-981-0993

Dr. Steven Broadstone
MIT Lincoln Labs
Advanced Techniques Group, MS D351
244 Wood Street
Lexington, Massachusetts
telephone: (617) 981-7440 email/misc. *srb@ll.mit.edu*
fax: (617) 981 0300

Dr. Irvin G. Stiglitz
MIT Lincoln Labs
Advanced Techniques Group
244 Wood Street
Lexington, Massachusetts
telephone: (617) 981-7440 email/misc.
fax: (617) 981 0300

WORKSHOP REGISTRANTS

(listed in order of organization)

Dr. V. Bheemineni
MRA Laboratories, Inc.
96 Marshall Street
North Adams, Massachusettes

telephone: (413) 664-4524 email/misc.
fax: (413) 663-5535

Dr. Bruce Johnson
Naval EOD Technology Division
R&D Division, Code 50A15
2008 Stump Neck Road
Indian head, MD 20640-5070
telephone: (301) 743-6850/248 email/misc.
fax: (301) 743-6947

Dr. Henry H. Chaskelis
Naval Research Laboratory
Mechanics of Materials Branch, Code 6380
4555 Overlook Avenue, SW
Washington, DC 20375-5320
telephone. (202) 767-3613 email/misc. *henry@sh.nrl.navy.mil*
fax: (202) 767-9181

Prof. Anthony J. Devaney
Northeastern University
Department of Electrical Engineering
Huntington Avenue
Boston, Massachusetts
telephone: (617) 437 5284 email/misc. *general*
fax: fax

Dr. Wallace Smith
Office of Naval Research
Materials Division, ONR 332
800 N. Quincy Street, Room 502
Arlington, VA 22217-5660
telephone: (703) 696-0284 email/misc.
fax: (703) 696-0934

Prof. W. Cao
Pennsylvania State University
Materials Research Laboratory
164 MRL
University Park, Pennsylvania
telephone: (814) 865-4101 email/misc.
fax: (814) 865-2326

Dr. W. Jack Hughes
Pennsylvania State University
ARL
Box 30
State College, PA 16804
telephone: (814) 865-1721 email/misc.
fax. (814) 863-7841

Professor K. Kirk Shung
Pennsylvania State University
Bioengineering Program
231 Hallowell Building
University Park, Pennsylvania
telephone: (814) 865-1407 email/misc.
fax: (814) 863-0490

Dr. Richard L. Tutwiler
Pennsylvania State University
ARL
Box 30
State College, PA 16804
telephone: (814) 863-2188 email/misc.
fax: (814) 863-7841

Dr. Thomas E. Linnenbrink
Q-Dot Incorporated
1069 Elkton Drive
Colorado Springs, Colorado

telephone: (719) 590 1112 email/misc. *general*
fax: (719) 590 1125 fax

Dr. Frederic L. Lizzi
Riverside Research Institute
330 West 42nd Street
New York, New York 10036

telephone: (212) 502-1774 email/misc. *(201) 567-1281 home*
fax: (212) 502-1729

Prof. Armen Sarvazyan
Rutgers University
Department of Chemistry
Busch Campus, P.O. Box 939
Piscataway, New Jersey
telephone: (908) 445-4792 email/misc. *Email sarvazyan@zodiac.rutgers*
fax: (908) 445-5312

Dr. Fred M. Dickey
Sandia National Laboratories
Optical Systems & Imaging Processing
MS 0843
Albuquerque, NM 87185-0843
telephone: (505) 844-9660 email/misc.
fax: (505) 844-4157

Dr. Mark E. Schafer
Sonic Technologies, Inc.
2935 Byberry Road
Hatsboro, Pennsylvania

telephone: (215) 957 2352 email/misc. *(215) 277 5652 home*
fax: (215) 957 2355

WORKSHOP REGISTRANTS

(listed in order of organization)

Alice A. Burgess
Strategic Analysis, Inc.
4001 N. Fairfax Drive
Suite 175
Arlington, VA 22203
telephone: (703) 527-5410 email/ misc.
fax: (703) 527-5445

Brenda Fischetti
Strategic Analysis, Inc.
4001 N. Fairfax Drive
Suite 175
Arlington, VA 22203
telephone: (703) 527-5410 email/ misc.
fax: (703) 527-5445

Jenny C. Fung
Systems Planning Corporation
1429 N. Quincy Street
Arlington, VA 22207
telephone: (703) 696-2265 email/ misc. jfung@dso.snap.org
fax: (703) 696-2201

Dr. Steven A. Johnson
TechniScan, Inc.
958 West LeVoy Drive
#200
Salt Lake City, Utah 84123
telephone: (801) 266-7700 email/ misc.
fax: (801) 261-1182

Dr. Alice Chiang
Teratech Corporation
President
223 Middlesex Turnpike
Burlington, MA 01803
telephone: (617) 891-4988 or email/ misc.
fax: (617) 270-6828

Dr. Dennis Dietz
Tetrad Corporation
Systems Development
357 Inverness Drive S.
Englewood, Colorado 80112
telephone: (303) 754-2320 email/ misc.
fax: (303)

Dr. Clyde G. Oakley
Tetrad Corporation
Systems Development
357 Inverness Dr. S.
Englewood, Colorado 80112
telephone: email/ misc. (303)
fax: (303) 754-2315

Alexander J. Patrick, Jr.
Textron Defense Systems
Energy Technology
2385 Revere Beach Parkway
Everett, MA 02149
telephone: (617) 381-4173 email/ misc. none
fax: (617) 381-4160

Dr. Robert Asaro
Trans-Science Corporation
7777 Fay Avenue
Suite 112
La Jolla, California 92037
telephone: (619) 459-1240 email/ misc.
fax: (619) 459-0210

Dr. G.A. Hegemier
Trans-Science Corporation
7777 Fay Avenue
Suite 112
La Jolla, California 92037
telephone: (619) 459-1240 email/ misc.
fax: (619) 459-0210

Dr. Akhilesh Maewal
Trans-Science Corporation
7777 Fay Avenue
Suite 112
La Jolla, California 92037
telephone: (619) 459-1240 email/ misc.
fax: (619) 459-0210

Prof. John M.Cornwall
UCLA
Department of Physics
Los Angeles, CA 90095
telephone: (310) 825-3162 email/ misc.
fax: (310) 206-5668

Robert H. Grills
Ultra Image International
Marketing and Business Development
Two Shaw's Cove, Suite 101
New London, CT 06320
telephone: (203) 442-0100 email/ misc.
fax: (203) 442-2389

Dr. Robert W. Gill
Ultrasonics Laboratory
Division of Radiophysics, CSIRO
126 Creville St.
Chatswood, NSW 2067,
telephone: (61-2) 412-6006 email/ misc.
fax: (61-2) 411-5708

WORKSHOP REGISTRANTS

(listed in order of organization)

Dr. David E. Robinson
Ultrasonics Laboratory
Division of Radiophysics, CSIRO
126 Creville St.
Chatswood, NSW 2067,
telephone: (61-2) 412-6003 email/misc.
fax: (61-2) 411-5708

Dr. Charles S. Desilets
UltraSound Solutions
1215 Highland Drive
Edmonds, Washington
telephone: (206) 775-4724 email/misc. *(206) 672 2784 home*
fax: (206) 775-4724 fax

Prof. Joie Pierce Jones
University of California at Irvine
College of Medicine
Department of Radiological Sciences, RM B140
Irvine, CA 92717
telephone: (714) 824-6147 email/misc. *jpjones@uci.edu*
fax: (714) 824-6532

Prof. Matthew O'Donnell
University of Michigan
Electrical Engineering and Computer Science Department
Biomedical Ultrasonics Laboratory
Ann Arbor, Michigan
telephone: (313) 764-8589 email/misc. *(313) 763-5488*
fax: (313) 936-1905 fax

Dr. Chandra M. Sehgal
University of Pennsylvania
Department of Radiology
341 Stemmler Hall 36th & Hamilton Walk
Philadelphia, Pennsylvania
telephone: (215) 349-5461 email/misc. *general*
fax: (215) 349-5115

Dr. Bernard D. Steinberg
University of Pennsylvania
Valley Forge Research Center
200 S. 33rd Street
Philadelphia, Pennsylvania
telephone: (215) 898-6352 email/misc.
fax: (215) 573-2068

Prof. Kevin J. Parker
University of Rochester
Department of Electrical Engineering
518 Computer Studies Building
Rochester, New York 14627
telephone: (716) 275-3294 email/misc. *(716) 271-8433 home*
fax: (716) 275-2073

Prof. Jonathan Ophir
University of Texas Medical School
Dept of Radiology, MSB 2130
6431 Fannin
Houton, TX 77030
telephone: (713) 792-5842 email/misc. *jophir@msrad3.med.uth.tmc.edu*
fax: (713) 792-5645

Dr. Kirk Beach
University of Washington
Surgery, RF-25
Seattle, Washington
telephone: (206) 543-3827 email/misc.
fax: (206) 543-8136

Dr. Lawrence A. Crum
University of Washington
Applied Physics Laboratory
1013 North East 40th Street
Seattle, Washington
telephone: (206) 685-8622 email/misc. *(206) 543-1300 general lac@anchor.apl.washingto*
fax: (206) 685-8621 fax

Prof. Roy Martin
University of Washington
Anesthesiology & Bioengineering
Room RR-450, Health Science Bldg, MS RN-10
Seattle, Washington
telephone: (206) 685-1883 email/misc. *rmartin@car.u.washington.edu*
fax: (206) 685-3079 fax

Dr. Ronald A. Roy
University of Washington
Applied Physics Laboratory
1013 NE 40 Street
Seattle, WA 98105
telephone: (206) 543-7721 email/misc. *rroy@apl.washington.edu*
fax: (206) 543-6785

Dr. Joan Sanders
University of Washington
Department of Bioengineering
MS WD-12
Seattle, WA 98195
telephone: (206) 685-8296 email/misc.
fax: (206) 543-6124

Dr. Florence Sheehan
University of Washington
MS RG22
HSB RR616
Seattle, Washington
telephone: (206) 543-4535 email/misc.
fax: (206) 685-9394

WORKSHOP REGISTRANTS

(listed in order of organization)

Dr. Brent Stewart
University of Washington
Department of Radiology
MS RC-05
Seattle, WA 98195
telephone: (206) 548-6252 email/ misc. *bstewart@u.washington.edu*
fax: (206) 543-3495

Dr. Mark R. Holland
Washington University
Physics Department, Lab for Ultrasonics
Box 1105, One Brookings Drive
St. Louis, Missouri 63130
telephone: (314) 935-6402 email/ misc. *(314) 725 8732 home*
fax: (314) 935-5868 fax *jgm@wuphys.wustl.edu*

Abstracts

UP-VFRC-2-95 January 1995

BASIC PROBLEMS IN ABERRATION CORRECTION*

Bernard D. Steinberg
Valley Forge Research Center
The Moore School of Electrical Engeineering
University of Pennsylvania
Philadelphia PA 19014
steinber@pender.ee.upenn.edu

Aberrated ultrasonic wavefronts produce aberrated images. Aberration arises from two processes, incoherent scattering and coherent interference. Local speed perturbations about the average propagation speed in tissue are responsible for scattering. Discreet jumps at or across tissue boundaries cause the latter.

For totally unrelated physical reasons the spatial extent of these phenomena are much the same. Both scattered fields and multipath arrivals from, say, refraction cluster about the direct path with radii of a few degrees. Consequently, it is easy to confuse the two. Worse still, the total distortion field appears highy complicated structually because it is the coherent sum of fields caused by at least two different types of independent phenomena. The scattered field produces a clutter-typehalo about the direct return from a target, much like atmospheric humidity causes a ring around the moon. Coherent interference produces distinct multipath arrivals.

Because both fields cluster close to the path of the direct target echo, broad beams from small transducers tend to resolve neither. The high resolution echoscanners of the next generation (large, 2-D array systems), however, will be plagued with loss of contrast due to scattering and to false targts due to multipath. Adaptive phase deaberration corrects the former to a large extent (15-20 dB). It does nothing for the latter.

* Presented at ARPA/ONR Medical Ultrasonic Imaging Technology workshop, Lansdowne VA, 24-26 January 1995.

TWO-STEP ABERRATION CORRECTION

M. O'DONNELL^, SRIRAM KRISHNAN^ and K.W. RIGBY~
^Electrical Engineering and Computer Science Department
University of Michigan, Ann Arbor, MI 48109-2122
~Corporate Research and Development Center, General Electric Company
Schenectady, NY 12301

The phase sensitive signal recorded by a transducer array can be used to compute the cross-correlation function between all nearest neighbor element pairs. From these measures, the phase error function across the array can be estimated. Corrected images can then be formed by offsetting beam forming delays on both transmit and receive according to the measured error function. A phased array imaging system capable of real-time phase aberration correction has been constructed to test the method. Results, including real-time corrected images, will be presented demonstrating the potential for aberration correction with this system.

If aberrations can be accurately modeled simply as time delay, or phase, errors, then correlation processing, as implemented in the real-time scanner described above, can provide nearly ideal corrections. Recent work from several laboratories, however, has questioned whether a simple phase screen model is adequate to describe aberrations in medical ultrasound. These studies show that both the amplitude and phase vary across the aperture. A more complete phase aberration correction system, therefore, must correct for both phase and amplitude errors to minimize the effect of index of refraction variations on large array image quality.

To overcome the limitations of the correlation based method, we have examined additional aberration correction schemes minimizing the effects of both amplitude and phase errors. The most successful is a two-step procedure. First, major phase aberrations are removed with the correlation based system. Then, an adaptive compensation routine is applied to remove beam forming artifacts due to amplitude aberrations and any residual phase errors. The adaptive routine, called PARCA (Parallel Adaptive Receive Compensation Algorithm), minimizes image artifacts due to imperfections not corrected by the correlation-based method.

Experimental results on 128 and 64 channel systems will be presented for two different tissue equivalent phantoms to highlight some of the benefits and limitations of aberration correction using PARCA. Overall, the compensation algorithm is able to fully recover image quality for moderate phase and amplitude aberrations. These results strongly suggest that the two-step procedure should produce a robust system for full aberration correction in medical ultrasound.

M. O'Donnell
EECS Department
University of Michigan
Ann Arbor, MI 48109-2122
Tel: 313-764-8589
FAX: 313-936-1905
Email: odonnel@eecs.umich.edu

I prefer an oral presentation
My presentation requires two 35 mm slide projectors.

PHASE ABERRATIONS IN QUANTITATIVE ULTRASONIC IMAGING

J. H. Rose*, M. R. Holland+, M. Bilgen*, K.W. Hollman+, S. A. Wickline+ and J. G. Miller+
*Center for NDE, Iowa State University, Ames, IA 50011
+Departments of Physics and Cardiology, Washington University,
St. Louis MO 63130

The premise that underlies this presentation is that cross-fertilization between the medical and materials communities may contribute to successful approaches for overcoming limitations to ultrasonic imaging imposed by phase aberrations in inhomogeneous, anisotropic media such as soft tissue. ARPA initiated a program in the early 1970's aimed at developing the scientific fundamentals for quantitative nondestructive evaluation (QNDE) that provided significant insights into the effects of phase aberration on ultrasonic imaging. Two-dimensional imaging arrays were developed by two different subgroups (G. Kino at Stanford and K. Lakin, at USC and ISU) in the mid to late seventies. However, the work was abandoned in the early 1980's in part because of significant phase aberrations even in apparently uniform plates of metal. Substantial efforts were devoted to finding alternative methods for flaw characterization based on broadband inverse scattering theory, which led to the development of the inverse Born approximation. However, phase aberrations were also found to be the limiting problem in the successful implementation of these inverse scattering methods. A knowledge of the origin of phase aberrations in metal plates may provide insight into the corresponding medical imaging problem. The most important source of phase variations in structural solids are small (several percent) unknown anisotropies in the sound velocity that arise due to the forging or rolling of the plate. We have reported anisotropies of similar magnitudes in the velocity of myocardial tissue. Rough and irregular surfaces (loosely analogous to subcutaneous fat layers) are a second source of phase variations in metal parts. Irregularities in the shape of the scatterer (such as roughness) can also severely degrade the ability to size the flaw. Several methods have been proposed for the correction of aberrations. One uses a broadband signal and knowledge of the low- and high-frequency asymptotics of the flaw's scattering amplitude, with the low-frequencies determining the centroid of the flaw and the high frequencies determining sharp boundaries of the crack or void. Another method of correction involves inversion of the scattering data using a priori assumptions about the nature of the flaw. Still another approach to reducing phase aberration involves finding a point scatterer that is near the region of interest, and then focusing the array on that known point scatterer. Similar approaches have been discussed in the medical imaging literature and an important variant of the last approach is the time-reversal mirror of Fink et al. We will discuss some of the fundamental physical processes that give rise to phase aberrations and compare the results of several proposed solutions in an effort to make available to the biomedical community some of the results investigated by the QNDE community.

Supported in part by the National Institutes of Health (HL 40302 and 42950)

Dr. James H. Rose
Center for NDE
Iowa State University
Ames, IA 50011
Phone (515) 294-7537
FAX (515) 294-7771
Email: jrose@cnde.iastate.edu

I prefer an oral presentation.

Quantitative Three-dimensional Ultrasound Imaging

Anthony J. Devaney*
Department of Electrical and Computer Engineering
Northeastern University
Boston, MA 02115

January 20, 1995

ABSTRACT

The general theory of quantitative imaging of three-dimensional, semi transparent (soft tissue) objects using acoustic waves is presented. The theory is developed for the case of transmission type experiments appropriate to ultrasound diffraction tomography but is applicable with minor modifications to reflection geometries appropriate to pulse echo imaging. The imaging problem is formulated from first principles in terms of the three-dimensional acoustic wave equation and is shown to reduce ultimately to an inverse scattering problem. By use of certain linearizing approximations the inverse problem is shown to reduce to a conventional (coherent) imaging problem having a well defined point spread function (PSF) that can be computed in terms of the experimental parameters and imaging geometry. It is shown that this formulation allows quantitative acoustical imaging to be treated completely analogously to coherent optical imaging and, in particular, leads to a characterization of image quality in terms of the PSF and its spatial Fourier transform, the coherent transfer function (CTF). Inherent limitations of three-dimensional imaging are discussed based on the computed PSF for certain canonical geometries. These limitations are shown to be partially overcame by using suites of scattering experiments and/or beam scanning techniques such as focus-on-transmit and focus-on-receive. The talk includes a discussion of the validity of the weak scattering approximations that underlie the imaging model as well as discussion of the use of the wave aberration function for characterizing image quality. The talk is illustrated with simulated experimental results.

---

*Also with A.J. Devaney Associates, 355 Boylston St., Boston, MA 02116

WAVEFORM ABERRATIONS IN AN ANIMAL MODEL

B. S. Robinson, A. Shmulewitz, T. M. Burke, and J. E. Powers
Advanced Technology Laboratories
PO Box 3003, Bothell, Washington 98041-3003

A major obstacle facing medical ultrasound is the suboptimal image quality seen in a large percentage of patients due to wavefront distortions imposed by inhomogeneous tissue. More universal application of ultrasound requires that this patient dependency be reduced or eliminated. This is especially important in emergency, battlefield, and other remote applications where size and portability requirements rule out other more costly technologies such as CT or MRI.

Most correction techniques proposed to date assume a simple lensing distortion that can be largely removed by delay corrections. However, none of these techniques have demonstrated significant improvements of in vivo images. This can be attributed to three factors:

- the aberrations are not due to simple delay distortions but are the result of spectral, multipath and other distortions,
- the effects are 3D in nature and cannot be compensated using conventional 1D arrays, and
- the implementations tried to date do not have sufficient complexity (delay precision, number of channels, array dimensionality, real-time, etc) to accomplish the goal.

Animal experiments have been performed which verifies the first two of these claims, ie. that the aberrations are more complicated than pure delays, and that they are 3D in nature and will require 2D arrays to compensate.

Using a live pig model, data was acquired from individual elements of a 48 channel, 2.5 MHz phased array in both transmission and backscatter modes. Analysis of "first arrival" segments revealed arrival time variations of 21 ns RMS, peak correlations below 0.6 (implying spectral distortions), and amplitude variations of 7 dB when the full (13 mm) elevational aperture of the receiving array was applied at the skin surface. Arrival time variations increased to between 41 and 70 nSec RMS (depending on array orientation) when the elevational aperture was stopped down to 1 mm showing the 3D nature of the effect and the averaging due to the larger aperture. In addition, significant "multi-path" energy was observed in the period following the first main arrivals. Delay aberrations were reduced to below 6 ns RMS following removal of the abdominal wall when the full elevational aperture was applied at the liver capsule. Progressive dissection of the abdominal wall layers produced little qualitative improvement in image quality after removal of the subcutaneous fat layer (in the first 1 cm) but noticeable improvements were observed when the entire abdominal wall (4 cm total) was removed.

Jeff Powers, Ph.D.
ATL, MS 265
PO Box 3003
Bothell, WA., 98041-3003
Phone: (206) 487-7126
Fax: (206) 486-5220
Email: jpower@atl.com
I prefer an oral presentation requiring a slide projector.

TOPICS IN ULTRASONIC IMAGING.

D.E.Robinson, Y.Li, D.A.Carpenter, G.Kossoff
Ultrasonics Lab., Div. of Radiophysics, CSIRO
126 Greville St., Chatswood, NSW 2067, AUSTRALIA.

Substantial improvements in the quality of ultrasonic images of tissue are likely to come from developments in two areas. The use of true three-dimensional data obtained from a 2-D aperture will reduce the scanning required for the examination of a volume of tissue, and provide the basis for a more complete data set from ultrasonic scanning for more sophisticated display and automated or remote image interpretation. The development of algorithms to correct the aberrations caused by tissue inhomogeneities will provide clearer images, and allow ultrasound to be used with greater diagnostic accuracy on many more people and in a wider variety of conditions. Access to 3-D data will also enhance the performance of aberration correction algorithms. The Ultrasonics Lab. (UL) is currently active in both areas.

In collaboration with GEC-Marconi Systems in Australia we are developing a 3-D ultrasonic imaging system for use in sea-water. It uses a sparse array with an aperture of tens of centimeters and a frequency in the low Megahertz range. The data size dictates that novel, compact image-forming techniques be used, and these are a suitable area for collaborative generic research for medical applications.

Two approaches are being pursued for aberration correction. The STARS system is based on a forward modelling technique, and is directed at removing aberrations caused by superficial tissue overlying the examined area. It operates by imaging the superficial layers, and using *a priori* information to interpret the identity of the anatomical structures imaged to derive a set of corrections to the focussing algorithm. A method based on data redundancy has also been developed which overcomes shortcomings in the existing techniques and allows corrections to be made for aberrations deep in the image. Both techniques have been demonstrated using live human data. Further research is necessary on the properties of tissue which cause aberration and robust algorithms to reduce them.

The CSIRO Ultrasonics Laboratory (previously the Ultrasonics Institute, Australian Federal Dept. of Health) has been involved in Medical Ultrasonics research since 1959. It transferred to the CSIRO (Commonwealth Scientific and Industrial Research Organisation) in 1989, which encourages commercial collaborations.

Dr. David E Robinson
Ultrasonics Laboratory
Division of Radiophysics, CSIRO
126 Greville St.
Chatswood NSW 2067
Phone: (Intl 61-2) 412 6003
Fax: (Intl 61-2) 411 5708
Email: drobinson@ul.rp.csiro.au

I prefer an oral presentation.
My presentation requires the following facilities: 35mm slide projector.

THREE DIMENSIONAL CARDIAC ULTRASOUND - THE NEXT GENERATION

Roy W. Martin, Ph.D. and Florence H. Sheehan, M.D.*
Departments of Anesthesiology, Bioengineering and Medicine*,
RN-10, University of Washington, Seattle WA 98195

The heart is an elegant but complex three dimensional (3D) organ. Two dimensional (2D) ultrasound allows non invasive assessment but requires complicated mental assemblage of these 2D images to diagnosis abnormality in the 3D heart. The full disease involvement or interrelationship of regionally separated impairment may be overlooked, easily underestimated, or misunderstood. Three dimensional ultrasound offers the potential to provide a more complete analysis of the size, shape, and function of the left ventricle, mitral valve, and other structures. It also provides a powerful form for studying the interrelationship of the individual regions of the heart and how disease effects these. Moreover, it provides a format in which less training is required to quickly learn and understand cardiac function and perhaps perform diagnoses. In the mid 1970's investigators at the University of Washington began exploring the use of 3D imaging for this application. Later, in the mid 1980's, the current team began investigating transesophageal 3D cardiac imaging (3D TEE) by developing a 3D scanning probe that could be placed in the esophagus. Since that time we have made advances in 3D probes, 3D data acquisition and in 3D image analysis and display. We summarize these areas:

1. A dual axis multiplane transesophageal echo probe has been recently designed and built for more complete 3D image acquisition and which includes means for external body reference location.
2. A miniaturized 3D spatial and 3D angular (6D) location device which uses magnetic techniques has been developed to allow complete visualization of any cardiac structure from multiple windows and subsequent assembly of all imaging planes in 3D space.
3. A multimedia workstation has been assembled for automating the acquisition of respiratory and electrocardiographically gated ultrasound images in digital format, and for facilitating their coordinated analysis.
4. Semiautomatic procedures have been coded for image segmentation.
5. Methods have been developed for 3D reconstruction of the left ventricle and mitral valve apparatus(including sterographic projection) and for analysis of parameters such as regional wall motion in 3D and mitral valve annular dimensions.
6. Finally, procedures have been worked out for experimental clinical validation of equipment function and the accuracy of calculated parameters. We have dedicated laboratories for probe development and in vivo animal experimentation, as well as access to patients in three major medical centers.

Our investigative team consists of participants from cardiology, anesthesiology, surgery, bioengineering, electrical engineering and statistics/morphometrics. The University of Washington team's approach to 3D imaging and analysis is at the forefront in developing the methodology for complete structural and functional characterization of the heart. This methodology has a long range potential in clinical diagnosis and treatment assessment, for example in the evaluation of patients undergoing cardiac surgery and in developing and evaluating new surgical procedures.

I prefer an oral presentation. My presentation requires the following facilities (VCR/monitor and 35 mm slide projector).

Roy W. Martin, Ph.D.
University of Washington, RN-10
HSB RR450, Seattle, WA 98195
Phone: (206) 685-1883
Fax: (@06) 685-3079
Email: Rmartin@u.washington.edu

REAL-TIME ULTRASONIC TOMOGRAPHY

by
MS Good, GJ Posakony, SR Doctor, RK Littlefield and MA Lind

Inexpensive, portable diagnostic imaging systems can play a key role in decreasing battlefield fatalities and reducing the cost of military and civilian health care. Fast inexpensive computing technology will facilitate major breakthroughs in health care based on advanced diagnostic imaging. The evolution of 2-D acoustic transducer array technology with its associated beamforming electronics and reconstruction procedures will offer major improvements in both image resolution and quality by use of combined reflection and transmission modes to correct for aberrations in ultrasound propagation. One can envision an imaging "bed" containing an array of high resolution ultrasonic transducers which will allow the physician to visualize much of the patient's physiology. This bed might be integrated with other modalities (e.g., EKG, EEG, MRI, CAT) to augment and complement diagnostic processes.

In non-medical imaging applications, the use of traditional ultrasound beamformers such as ultra wideband holography and synthetic aperture focusing techniques (SAFT) have demonstrated substantial improvements in signal-to-noise ratios and resolution for 3-D volumetric imaging. A wide variety of signal processing algorithms have been developed to overcome unique problems involving acoustic anisotropy of the media being insonified. But, because most insonifications are aperture limited, the biggest improvements result when the effective aperture is increased.

The standard ultrasonic tomographic imaging approach uses a ring containing many ultrsasound transducer elements to eliminate the aperture limitations. This ring forms a 2-D cylindrical array which is coupled to the patent using an expandable water bladder. The advantage of this approach is the regular geometry which permits faster and more accurate reconstruction. A variation in this approach is a flexible 2-D array placed in contact with the patient. The advantage of the flexible array is that it can be quickly applied to any location on the patient. The major difficulties of this approach are determining the accurate location of each transducer and the use of more complex and slower reconstruction processes.

The tomographic approach creates an image by transmitting with a single small element of the array to achieve a divergent ultrasonic field. All transducers receive signals and each transducer is systematically also used as a transmitter. An inversion process is performed on the resulting data to reconstruct a high resolution 3-D volumetric image. The wideband, high aperture insonification coupled with frequency dependent inversion processes including cut and split spectrum algorithms can compensate for the acoustic impedance variations to form high quality images.

The major technology gaps hindering the implementation of real-time 3-D ultrasound tomographic imaging are the fabrication of large (10,000 cm^2) high density acoustic transducer arrays and availability of faster (100X) inexpensive computers. With inexpensive computation power increasing by 10X every five years, array fabrication is target of opportunity over the next five to ten years.

TIME FOR A NEW PARADIGM FOR ULTRASONIC MEDICAL IMAGING

David Vilkomerson
EchoCath, Inc.
Princeton, NJ

Present medical ultrasound instruments have evolved into highly effective instruments following a particular paradigm: cross-sectional images are produced at "real-time" frame rates as a skilled operator, the sonographer; manually sweeps a scanhead over the patient's body. The sonographer selects a series of these images to be interpreted by an ultrasound-trained physician, usually a radiologist.

This paradigm was evolved when the only way to integrate the scanned information into a meaningful model of three-dimensional anatomy was in the mind of a well-trained, highly-experienced observer. Perpendicular cross-sections, known as the transverse and longitudinal views, of the region of interest are interpreted in the observer's mind as normal or pathological structures.

There are now other ways of decoding the scanned information. Modern digital processors can produce three-dimensional volumetric images from backscattered ultrasound. With the proper segmentation of the ultrasound information, i.e. recognition of the differing tissue types encountered by the ultrasound, this information can be presented in a form understandable by inexperienced observers.

We propose that ultrasound imaging systems based on three-dimensional reconstruction of ultrasound data automatically acquired and segmented should be developed. Such systems would require neither sonographers nor ultrasonically trained physicians. These systems would significantly expand the utility of ultrasound, not only in permitting defense applications in a near front-line environment, but in civilian emergency rooms as well. Ultrasound imaging systems like this would expand the usefulness of ultrasound imaging for surgeons and general practice physicians, improving health care and reducing costs.

In this presentation, we will discuss the three major elements of such a new ultrasound system: automatic volumetric scanning, tissue identification, and three-dimensional representation of anatomy. Analysis of the system characteristics, e.g. time, needed for automatic scanning, system computing requirements for tissue identification, and system display needs for anatomical representation will be presented. The particular applicability of two-dimensional arrays for such systems will be noted. New uses for such ultrasound imaging will be hypothesized.

Dr. David Vilkomerson
Executive Vice-President
EchoCath, Inc.
P.O. Box 7224
Princeton, NJ 08543-7224

E-mail DVilk@aol.com
609/987-8400, Ext 12
609/987-1019 Fax

I prefer an oral presentation. I will require a VCR/Monitor (S-VHS?) and slide projector.

VOLUMETRIC ULTRASONIC ASSAYS OF TISSUE MICROSTRUCTURE AND BLOOD FLOW

F.L. Lizzi, E.J. Feleppa, K.W. Ferrara
Riverside Research Institute
330 West 42nd Street, New York, NY 10036

Conventional ultrasonic visualization methods map complex tissue structures into video images whose gray-scale values are not easily related to underlying tissue properties, even in high-resolution images. Several laboratories, including our own, have found that non-conventional processing of radio-frequency (rf) echo signals can extract additional, clinically important information about tissue microstructure. Similarly, non-Doppler flow-measuring techniques are providing additional quantitative information regarding blood flow within tumors and in the surround.

This presentation reviews our recent results to indicate the status of these techniques and to identify research topics warranting further investigation. Our tissue-parameter assays use temporal- and frequency-domain analyses to estimate the effective sizes, concentrations and acoustic impedances of sub-resolution tissue constituents; our blood flow assays employ a mixed-domain method to improve the spatial resolution, accuracy and dynamic range of velocity estimates. Our results in the eye, prostate, and breast indicate that comprehensive assays should include several complementary features. Volumetric 3-D assays are required for reliable differential diagnosis and for sub-classifying individual tumors in terms of potential lethality and likely responsiveness to particular therapeutic approaches. The statistical dispersion of constituent scatterer properties and the presence of sub-regions with different mean properties are of particular importance in these assays. Volumetric multi-parameter assays are also proving crucial in delineating tissue sub-volumes that are successfully modified by treatment modalities including radiotherapy, hyperthermia, and ablation.

Further exploitation of these promising non-conventional methods requires research into: fundamental scattering and propagation topics; advanced signal processing and 3-D analysis procedures; and transducer configurations and insonification patterns tailored to optimize these concepts.

Dr. F.L. Lizzi
Biomedical Engineering Laboratories
Riverside Research Institute
330 West 42nd Street
New York, NY 10036
Phone: (212) 502-1774
FAX: (212) 502-1729

I prefer an oral presentation.
My presentation requires the following facilities (VHS/VCR monitor)

MULTIORGAN DIAGNOSTIC SCREENING AND MINIMALLY INVASIVE THERAPY WITH PORTABLE ULTRASOUND

C.G. Oakley, L.J. Busse, D.R. Dietz
Tetrad Corporation
357 Inverness Dr. S., Suite A
Englewood, CO 80112

The greatest potential for impacting combat casualty care is with a hand carried instrument that can be used for organ assessment, to guide therapy, and to reduce blood loss. Of all of the imaging modalities, ultrasound is the best suited for this task. External probes can be used for multiorgan assessment. Laparoscopic probes that guide minimally invasive therapy tools can be used to treat injuries. Communication of video images and 2-D and 3-D ultrasound images of internal organs can enable a surgeon at a remote site to direct the therapy.

There are several important technologies required to implement this type of instrumentation that are under development by Tetrad and that are being used in minimally invasive therapy. Laparoscopic probes of 10mm and 5mm diameter have been developed with accessories for guided therapy. Further developments in transducer technology are needed to reduce cost, to reduce size, and to increase the robustness of these devices for field use. Encoding of laparoscopic probes and surgical ports provides a convenient method for collecting 3-D data sets. Imaging systems with automated controls for use in surgery have been developed. Through customization, hand carried versions become practical. Speckle reduction shows promise in making ultrasound images easier to interpret and to enable 3-D display of internal organs as part of trauma and therapy planning.

Dr. C.G. Oakley
Tetrad Corp.
357 Inverness Dr. S., Suite A
Englewood, CO 80112
303-754-2315
fax 303-754-2329

HAND-HELD ULTRASOUND

M. O'DONNELL and M. KARAMAN
Electrical Engineering and Computer Science Department
University of Michigan, Ann Arbor, MI 48109-2122

Highly mobile and low-cost ultrasound systems have been manufactured for a long time. They are not routinely used in the clinic, however, because of dramatically reduced image quality compared to the current state of the art in real-time scanners. A high quality, real-time imager must be agile yet maintain good imaging performance, determined primarily by penetration (i.e., electronic SNR), and both spatial and contrast resolution. Agility includes selectable scan formats, Doppler and color flow processing, and advanced signal and image processing. If highly portable systems are to be used routinely, even replacing stationary systems for applications such as combat casualty care, then the overall quality must approach that of current high-end imagers. The primary objective of the work presented here is to develop high quality, real-time ultrasound scanners with dramatically improved portability leading ultimately to hand-held systems (i.e., "Scanman").

Because of the severe power and size constraints of a hand-held device, we have explored synthetic aperture imaging methods. Using both simulations and experiments, a multi-element approach has been tested. This technique uses an active multi-element receive subaperture, and a multi-element transmit subaperture defocused to emulate a single element spatial response with high acoustic power. Echo signals are recorded independently on each element of the receive subaperture. Following acquisition, an image is reconstructed using the complete data set with full dynamic focus on both transmit and receive. Various factors affecting image quality have been compared to conventional imagers through measurements on different phantoms with a 3.5 MHz, 128 element array. Results will be presented showing that multi-element synthetic apertures achieve higher electronic SNR and better contrast resolution than conventional synthetic apertures. Moreover, image quality approaches full phased array performance but with an order of magnitude less electronic channels.

Although providing good image quality with reasonable electronic SNR, synthetic imaging methods are subject to motion artifacts. To minimize this, we have examined an overlapping subaperture technique to estimate motion during data acquisition. Results of initial experiments using this method will also be presented.

M. O'Donnell
EECS Department
University of Michigan
Ann Arbor, MI 48109-2122
Tel: 313-764-8589
FAX: 313-936-1905
Email: odonnel@eecs.umich.edu

I prefer an oral presentation
My presentation requires two 35 mm slide projectors.

HIGH DEFINITION ULTRASONIC IMAGING

Irvin G. Stiglitz, Steven R. Broadstone, Gerald R. Benitz
MIT Lincoln Laboratory
244 Wood Street, Lexington, MA 02173

High Definition Imaging (HDI) techniques have been developed at M.I.T. Lincoln Laboratory for processing radar data, that provide an order of magnitude improvement in spatial resolution, suppression of artifacts due to scattering sources and clutter and the elimination of the sidelobes of the array response. Initial applications of these techniques for ultrasonic image processing has produced encouraging results. With HDI, quantitative estimates of the scattering characteristics of objects are obtained by confining the ultrasonic reflections to a one-dimensional, "ice-pick", view into the medium. The improvement is made without the loss in resolution that accompanies conventional techniques obtained using array appodization or shading. Early exploitation of these techniques have shown that HDI gives improved performance in the detection and identification of point-like objects in controlled environments (water and gelatin-filled medical phantoms) using a 32-element ultrasonic array at a frequency of 3.5 MHz. For these cases, ultrasonic data processed with the conventional methods obtained a lateral scattering resolution of several centimeters; HDI processing of the data improved the lateral resolution to 750 μm. This improvement allows the detection of low-level scatterers that are near other features, thereby providing more accurate measurements of anatomical features.

FACTORS AFFECTING THE ACCURACY AND STABILITY OF ADAPTIVE IMAGING USING TWO-DIMENSIONAL ARRAYS

G. E. Trahey, Ph.D.
Department of Biomedical Engineering, Duke University
Box 90281, Durham, North Carolina 27708

Most adaptive imaging schemes proposed for clinical ultrasound involve two steps: 1) measurement of arrival time profiles across the two dimensional receiver array and 2) correction of the timing of transmitted and received ultrasonic signals based on the measurements in (1). Achieving coherence across the entire two dimensional array surface over hundreds of element locations is made difficult by a number of factors including 1) echo signal decorrelation across the receive array resulting from the diffuse nature of tissue scatterers, 2) the limited depth of field of transmitted ultrasonic pulses, 3) the accumulation of timing errors across the array surface, 4) nonuniformities in elements' transfer functions, and 5) acoustic and electronic noise.

We present analytic, simulation, and experimental results which illuminate the significance of each of these factors in adaptive imaging with 2-D arrays. The impact of array geometry, algorithm selection for arrival time profile estimation, aberrating layer position, and tissue characteristics are also discussed. Schemes to improve image resolution and stability are presented.

Dr. Gregg E. Trahey
Department of Biomedical Engineering
Duke University
136 Engineering
Box 90281
Durham, NC 27708
Phone: (919) 660-5169
Fax: (919) 684-4488
Email: get@egr.duke.edu

I prefer an oral presentation.
My presentation requires a slide projector.

TWO-DIMENSIONAL ARRAYS FOR MEDICAL ULTRASOUND IMAGING

Stephen W. Smith
Departments of Biomedical Engineering and Radiology
Duke University, Durham, NC 27708 USA

Two-dimensional arrays are critical to the future of medical ultrasound for focusing and phase aberration correction in two dimensions as well as high speed volumetric imaging. Two major problems in the development of 2-D arrays include fabrication difficulties and low sensitivity. The element size (< .35 mm x .35 mm) results in small clamped capacitance and high electical impedance. Fabrication problems can be solved using multi-layer flexible circuit connectors consisting of poyimide layers < 25 um thick. Sensitivity can be dramatically improved by reducing the array element immpedance using an N layer structure of PZT connected electrically in parallel and acoustically in series. The clamped capacitance is multiplied by N^2 and the impedance by $1/N^2$ compared to a single layer control element. KLM and finite element computer simulations as well as laboratory experiments show reduction of element source impedance to 10 Ω and SNR increases of up to 40 dB for 2-D array transducers. In vivo scans using multi-layer PZT also show signficant improvements.

Address: Professor Stephen W. Smith
Department of Biomedical Engineering,
Box 90281
Duke University,
Durham, NC 27708 USA
Tel 919-660-5160
Fax 919-684-4488
sws@egrserve.egr.duke.edu

I prefer an oral presentation

A NOVEL ULTRASOUND THREE-DIMENSIONAL APPROACH

January 1995

A. Nicoli, N. Butler, T. White, M. Lasser
Loral Infrared & Imaging Systems
Lexington, Massachusetts 02173

ABSTRACT

Loral has demonstrated a 42 x 64 element ultrasonic receiving array. By overcoming the problem of interfacing the transducer elements with the sensor a major constraint is lifted from the system designer. By employing manufacturing and microelectronic multiplexing techniques originally developed for infrared imaging focal planes, Loral can make densely packed ultrasound arrays and capture (sample) the return signal from all elements at precisely the same time or at predetermined delay intervals. This paper will present the implications of this capability as seen by newcomers to the ultrasound community, as well as suggesting and seeking further improvements.

Silicon multiplexers and detector arrays of other materials have been fabricated for the military for many years. The techniques required are similar to those needed for large area ultrasound transducer arrays. With these techniques the limitations cease being detector wiring and related interface issues such as A/D conversion. A fully populated 128 x 128 transducer array with 4 to 6 mil elements is reasonable with existing technology. The primary constraints now are integrated circuit size (as determined by circuit yield and cost) and signal processing rate.

Mr. T. E. White
Loral Infrared & Imaging Systems
2 Forbes Road
Lexington, MA 02173
Phone: 617-863-3119
FAX: 617-863-4249
EMail: tim_white @liris.loral.com

I prefer an oral presentation with viewgraph machine.

"NON-INVASIVE SURGERY "APPLIED TO THE CONTROL OF HEMORRHAGE FROM BLUNT TRAUMA

Edward C. Driscoll, Jr., PhD.
FOCUS Surgery, Inc.
225 Hammond Ave., Fremont, California 94539

FOCUS Surgery has been developing technology for "Non-Invasive Surgery" based on High Intensity Focused Ultrasound (HIFU). Initial commercial applications are being pursued in the destruction of diseased tissue in benign and malignant disorders. The lethal tissue effect is principally the result of dramatic, rapid heating leading to coagulative necrosis in as little as fractions of a second, and with the precision of a few cell diameters. Moreover, this technology can non-invasively deliver useful, controlled and localized energy to soft tissue in the body for other beneficial applications. One potential example is to stimulate or promote localized coagulation non-invasively. This could be useful to control cases of internal hemorrhage. In battlefield conditions, it has been reported that a significant source of mortality is uncontrolled hemorrhage from blunt trauma in the first hours after injury. Furthermore, conventional surgical repair of diagnosed hemorrhage can often be difficult. Similar circumstances apply to civilian trauma cases. We believe our technology can be used to non-invasively target and coagulate tissue volumes that are experiencing hemorrhage, allowing for the stabilization of the patient and later surgical repair. This may be accomplished by optimized application of HIFU alone or in conjunction with pharmacologic agents.

Our presentation will cover the basic technology, capabilities and clinical trial status of our initial markets, and an overview of our research interests directed to this new application.

Edward C. Driscoll, Jr., PhD.
FOCUS Surgery, Inc.
225 Hammond Ave.
Fremont, California 94539
510 354 3702
510 353 1544 (Fax)

I prefer an oral presentation. (35mm slides)

DEVELOPMENT OF VERY HIGH FREQUENCY ULTRASONIC IMAGING SYSTEMS

JOIE PIERCE JONES
Department of Radiological Sciences, University of California Irvine
Irvine, CA 92717

Conventional medical ultrasound imaging systems operate between 1 and 10 MHz, frequencies chosen as trade-offs between resolution and depth penetration. Recently a number of new application areas have been developed at higher frequencies. For example, systems for intravascular and dermatological imaging operate at 20 to 50 MHz. In adddition, acoustical microscopy (100 MHz-1 GHz) is proving to be a useful technology for both fundamental as well as diagnostic studies. Here we make the case that the development of very high frequency (50-500 MHz) ultrasonic imaging technology utilizing recent developments in thin film transducer design could lead to a variety of new application areas and systems ranging from new research tools to new and more cost effective diagnostic instruments to simple devices that could be used in the field. Application areas include evaluation of burns and wounds; imaging of the skin; intravascular and laparoscopic imaging; and *in situ* and *in vitro* acoustical microscopy.

Joie Pierce Jones
Department of Radiological Sciences
University of California Irvine
Irvine, CA 92717
Phone: (714) 824-6147
FAX: (714) 824-6532
E-Mail: JPJONES@UCI.EDU

I prefer an oral presentation.
My presentation requires a 35 mm slide projector.

HIGH-FREQUENCY ACOUSTIC IMAGING FOR EARLY DETECTION OF SKIN BREAKDOWN

J.E. Sanders, R.A. Roy, and B.S. Goldstein
University of Washington, Seattle, WA 98195

In persons with spinal cord injury (SCI), pressure sores are a source of tremendous physical and emotional distress. They often result in increased disability and they can lead to an early death. Pressure sores occur in 35% to 40% of SCI patients at an estimated treatment cost of $25,000 to $50,000 per pressure sore.

Although the exact pathophysiology and development of pressure sores is unknown, a general understanding of the basic biologic events has slowly accumulated over the last 30 years. From prolonged sitting with minimal weight-shifting, excessive pressure and shear are induced, especially at bone/soft tissue interfaces, which cause blood and lymph vessel occlusion. Prolonged loading leads to tissue ischemia and necrosis and ultimately atrophy of superficial muscle, fat, and skin. Tissue reorganization, clinically evident as a macroscopic change in shape and distribution, can displace tissue away from bony sites. A sterile abscess or cyst deep in the muscle may form. Observed pathological changes in animal models include a loss of cross-striations in muscle and a reduction in the number of myofibrils; hemorrhage into loose connective tissue; cellular infiltrate within muscle; and a reduction in collagen fiber structures. Finally, skin begins to discolor and ultimately a pressure sore becomes visually apparent. There is a critical clinically-observed characteristic about this process: Once a pressure sore is recognized by clinical examination, extensive tissue damage and necrosis have already occurred. Frequently, the extent of ischemia and injury is already into deep and adjacent muscle tissue and extensive surgical repair is required.

We propose that high-frequency acoustic imaging could be used to image the early part of the degeneration process, thereby providing a way to identify non-invasively any sites at risk for pressure sore formation. Early detection would allow early treatment which would substantially reduce the suffering and expense associated with pressure sores. There is compelling evidence that high frequency ultrasound is a most appropriate imaging modality. Though measurements to date lack sufficient resolution for the purposes of early pressure sore detection, skin and muscle thickness and shape measurements have been made at 7.5 MHz. Similarly, substantial loss of muscle fiber striation patterns and presence of cellular infiltration have also been shown detectable, as have midsize-to-large sterile abscesses and hematomas. What is needed to facilitate the application of ultrasound technology to pressure sore detection is a unit with increased resolution. Penetration depths beyond 1 cm are not necessary since the pressure sores occur near the skin surface. With these specifications, it is clear that high-frequency ultrasound (>25 MHz) is potentially applicable. This should allow detection of small sterile abscesses and hematomas, while a frequency of >50 MHz should pick up collagen architectural changes and muscle striation alterations. Both narrow-band and broad-band modalities should be considered, as well as the role of changing frequency, angle of incidence, and scattering angle. Such a device, which could be manufactured inexpensively, would ideally be very portable (hand held) and designed specifically for the early detection and characterization of evolving pressure sores.

Corresponding author: J.E. Sanders PhD
Center for Bioengineering, WD-12
University of Washington
Seattle, WA 98195
phone: (206) 685-8296
FAX: (206)543-6124
Email: jsanders@u.washington.edu

I prefer an oral presentation. My presentation requires a slide projector.

ASSESSMENT OF ADVANCED LASER ULTRASONIC TECHNOLOGY

Robert H. Grills
Ultra Image International
Science Applications International Corporation

Alexander J. Patrick, Jr.
Textron Defense Systems

The use of lasers to generate ultrasonic signals is a well demonstrated technology. This technology has many unique features including non-contact, small focus point, ability to handle small radius of curvatures, and the potential of rapid scanning. However, the acceptance of this technology in the market place has been limited because of the complexity of the resulting hardware, signal processing problems, and the sensitivity of the laser ultrasonic system which limits its acceptance for use in a industrial setting.

Starting in 1988, Textron Defense Systems (TDS) began the development of a low cost, light weight, compact laser ultrasonic unit for industrial applications. The LaserWave™ unit has passed through a series of development activities starting with bench top experiments, prototype units, preproduction units and finally into product status. In 1993, TDS and Ultra Image International (UII) began a joint efforts to combine the LaserWave™ with UII's advanced imaging technology. This presentation will discuss the LaserWave™ ultrasonic accomplishments, UII's advanced imaging technology, and the plans and initial results from the joint development effort.

Robert H. Grills
Ultra Image International
2 Shaw's Cove Suite 101
New London, CT. 06302
Phone: 203-442-0100
Fax: 203-442-2389

Alexander J. Patrick, Jr.
Textron Defense Systems
2385 Revere Beach Parkway
Everett, MA. 02149
Phone: 617-381-4173
Fax: 619-381-4160

FUNCTIONAL ULTRASOUND

Robert W Gill, Lawrence S Wilson, Thanasis Loupas, George Kossoff
Ultrasonics Laboratory, CSIRO Division of Radiophysics
126 Greville St, Chatswood, NSW, 2067, Australia

Ultrasound, with its dynamic imaging and its capacity to display and characterise blood flow, inherently provides functional information about the patient. With present equipment, however, considerable skill is needed to acquire and interpret this information. In battlefield casualty medicine and civilian emergency care (eg ambulances and hospital emergency rooms) there is a requirement to help relatively unskilled operators to effectively acquire and interpret such functional information.

We propose the development of one or more packages which would integrate within a highly compact ultrasound machine the ability to assess a number of functional parameters, for example on the cardiovascular status of the patient, leading the user through a series of simple steps and assisting with the interpretation of the resulting data. This will require: (a) refinement of existing functional measurement capabilities of ultrasound equipment; (b) the development of new measurement techniques, and their tailoring for specific applications; (c) the development of "smart" ultrasound equipment requiring little or no operator control to optimise the data acquired; (d) standardised measurement protocols to lead the user through a specific series of measurements; (e) computer-aided diagnostic tools to assist in the interpretation of the results of the examination.

As a specific example, consider a system to assess the cardiovascular status of a patient, for example a battlefield casualty, who might be suffering from internal bleeding. A procedure such as the following could be applied: (a) ultrasound imaging is used to search for free fluid (blood) within the peritoneum and pleural spaces and around the kidneys; (b) the status of the heart is assessed, for example by estimating heart rate and cardiac output and obtaining a measure of heart wall contractility; (c) the circulatory system is assessed to identify signs of reduced blood volume and shock, eg by using a combination of colour flow imaging and pulsed Doppler to determine the perfusion of critical organs, such as the kidneys and liver, and blood flow to the limbs; (d) ultrasonic tissue characterisation is used to identify organs or tissue regions suffering from lack of oxygen. Additional measurement facilities could be built into the machine, such as a clip-on oximeter to determine peripheral blood oxygenation.

A second example could be the use of ultrasonic imaging to search for foreign objects such as shrapnel. In addition to the use of smart controls to automate the acquisition of optimum images, the machine could contain a library of normal appearances to assist the user to identify abnormalities, or computer-aided image interpretation could be used to automate this process. The development of computer image interpretation is already well advanced in areas of radiology such as mammography and chest X-ray diagnosis.

Dr Robert W Gill
Ultrasonics Laboratory
CSIRO Division of Radiophysics
126 Greville Street
Chatswood NSW 2067
Australia
Phone: (61 - 2) 412 6006
Fax: (61 - 2) 411 5708
Email: rgill@ul.rp.csiro.au

I prefer an oral presentation
My presentation requires the following facilities: 35 mm slide projector

THE USE OF DIAGNOSTIC ULTRASOUND FOR RADIOLUCENT SHRAPNEL DETECTION AND WOUND ASSESSMENT.

LAWRENCE A. CRUM
Applied Physics Laboratory
1013 NE 40th Street
University of Washington, Seattle, WA 98105
and
ROY W. MARTIN
Departments of Bioengineering and Anesthesiology
University of Washington, Seattle, WA 98195

In recent military conflicts involving US military personnel, 48% of the wounds were due to fragmentation devices, vs 10% from gunshots. A large percentage of these fragmentation devices are land mines, which are increasingly constructed of non-metallic, radiolucent materials. Consequently, the major efforts of mid-echelon combat casualty care units are to assess the degree of wound injury, to determine if there are destabilizing conditions for the patient (such as uncontrolled bleeding), and to locate entrained foreign objects that may result in subsequent massive infection. Conventional systems such as x-radiography can not detect the presence of radiolucent foreign objects, or physiological conditions such as hematomas, edema, and inflammation. More sophisticated techniques such as CAT and MRI are expensive and not portable. With sufficient modification and development, existing diagnostic ultrasound imaging systems can provide an extraordinary new level of diagnosis in combat casualty care; furthermore, these systems can be made portable, are relatively inexpensive, and would have immediate and broad application to civilian use in emergency rooms and trauma centers. The problem of unexploded ordinance and land mines is also a major third-world problem, with estimates of over 100 million undetected land mines existing and over 50,000 casualties/year occurring. We propose to utilize two new techniques in ultrasound technology--correlation enhancement and sonoelasticity, that would permit the adaptation or modification of the existing technology of diagnostic ultrasound for use in wound assessment and foreign object detection.

The DoD in-force requirements that address these needs are described in NAPDD 297-093, "Advanced techniques and products for combat wound management", promulgated 3/24/92 and NAPDD 295-093, "Fleet health care technology", promulgated 12/3/91.

I prefer an oral presentation; my presentation requires an overhead projector.

Dr. Lawrence A. Crum
Applied Physics Laboratory
1013 NE 40th Street
University of Washington
Seattle, WA 98105
Phone: (206) 685-8622
Fax: (206) 685-8621
Email: lac@apl.washington.edu

ELASTOGRAPHY: IMAGING OF TISSUE ELASTIC PROPERTIES IN *VIVO*

J. OPHIR, I. CESPEDES, N. MAKLAD, B. GARRA+, and H. PONNEKANTI
Ultrasonics Laboratory, Department of Radiology
University of Texas Medical School, Houston, TX 77030, and
+Department of Radiology, Georgetown University Medical Center,
Washington, DC 20007

It is well known that tissue elasticity is correlated with pathology. This fact forms the basis for palpation, which is routinely used in the clinic. The drawbacks of manual palpation are low sensitivity, specificity and limited size and depth of the palpable pathology. Some time ago we reported a new ultrasonic method for imaging the elastic properties of tissues in vivo. This method is known as Elastography, and the strain image produced is known as an Elastogram. Briefly, pairs of echo RF signals are acquired immediately before and after the application of a slight axial compression to the tissue. Segments of the echo signals are analyzed pairwise and local axial tissue displacements are estimated. The axial gradient of the displacement is computed. An image (elastogram) of this displacement gradient (strain) is then produced. This method allows imaging of small, deep hard or soft tumors and other pathologies.

As long as the stress field in the tissue remains uniform, the elastogram is proportional to the distribution of tissue elastic moduli. Such uniformity can be assured by correcting for boundary conditions, and so long as the elastic contrast in the tissue remains relatively low. Departure from these conditions produces recognizable image artifacts and less quantitative images.

We have constructed an apparatus for practicing elastography in the breast. It allows a direct comparison between sonograms and elastograms of a given anatomical site. We will demonstrate that (1) elastograms convey new information, and thus the elastographic appearance of breast tumors is different than their sonographic appearance, and (2) that it is possible to elastographically visualize known breast cancers which are poorly visualized or not visualized in sonograms. Other potential applications will also be discussed, as well as the factors affecting elastographic image quality.

Supported in part by NIH grants RO1-CA38515, RO1-CA 60520, and PO1-CA64597, and by a grant from Diasonics Ultrasound, Inc.

Prof. Jonathan Ophir
Ultrasonics Laboratory, Dept. of Radiology
University of Texas Medical School, 6431 Fannin
Houston, TX 77030
phone: 713-792-5842
fax: 713-792-5645
e-mail: jophir@msrad3 med uth tmc. edu

THE NEW THEORY OF SONOELASTICITY

K. J. PARKER, L. GAO, S. K. ALAM, D. J. RUBENS, R. LERNER
Rochester Center for Biomedical Ultrasound — University of Rochester
Hopeman Building, Room 203
Rochester, NY 14627

Sonoelasticity is a rapidly evolving medical imaging technique for visualizing hard tumors and other abnormalities in tissues. In this novel diagnostic technique, a low frequency vibration is externally applied to excite internal vibrations within the organs under inspection. A small stiff inhomogeneity in a surrounding tissue appears as a disturbance in the normal vibration pattern. By employing a properly designed Doppler detection algorithms, a real-time vibration image can be made. A theory for vibrations or shear wave propagation in inhomogeneous tissue has been developed. A tumor or foreign inclusion is modeled as an elastic inhomogeneity inside a lossy homogeneous elastic medium. A vibration source is applied at a boundary. The solutions for the shear wave equation have been found both for the cases with and without an inclusion. The solutions take into account varying parameters such as: inclusion size and stiffness, shape of vibration source, lossy factor of the material and vibration frequency. The problem of the lowest detectable change in stiffness is addressed using the theory, answering one of the most critical questions in this diagnostic technique. Some experiments were conducted to check the validity of the theory, and the results showed a good correspondence to the theoretical predictions. These studies provide basic understanding of the phenomena observed in the growing field of clinical sonoelasticity imaging.

Dr. K. J. Parker
Rochester Center for Biomedical Ultrasound
University of Rochester
Hopeman Building, Room 203
Rochester, New York 14627
Phone: (716) 275-3294
Fax: (716) 473-0486
Email: parker@ee.rochester.edu

[I prefer an oral presentation, with VCR and dual projection.]

CLINICAL USES OF SONOELASTICITY

D. J. RUBENS, K. J. PARKER, L. GAO, S. K. ALAM, R. LERNER
Rochester Center for Biomedical Ultrasound — University of Rochester
Hopeman Building, Room 203
Rochester, NY 14627

Two hospitals in Rochester, New York, are currently evaluating sonoelasticity for real-time clinical uses. Evidence is mounting that sonoelasticity is applicable to a variety of organs and complements the information available with conventional B-scan information. The detection of tumors in the prostate, liver, and breast is a primary focus of sonoelasticity. *In-vivo* and *ex-vivo* images compared with pathology results demonstrate that sonoelasticity improves sensitivity and provides a useful demarcation of the tumor-tissue boundary. This work is also extended to the detection of isoechoic foreign particles, for both civilian and military applications. Furthermore, quantitative applications of sonoelasticity are under development, utilizing the resonance behavior of the eye, the liver, and other organs. These are useful for characterizing the time-dependent bulk mechanical properties of tissues, with applications to a broad class of diseases and injuries. Real-time images from clinical studies will be presented to illustrate the state of the art of sonoelasticity.

Dr. K. J. Parker
Rochester Center for Biomedical Ultrasound
University of Rochester
Hopeman Building, Room 203
Rochester, New York 14627
Phone: (716) 275-3294
Fax: (716) 473-0486
Email: parker@ee.rochester.edu

[I prefer an oral presentation, with VCR and dual projection.]

A NEW APPROACH TO REMOTE ULTRASONIC EVALUATION OF VISCOELASTIC PROPERTIES OF TISSUES FOR DIAGNOSTICS AND HEALING MONITORING

A. P. SARVAZYAN

Department of Chemistry, Rutgers University, New Brunswick, NJ 08903.

The objective of this research is to develop a new approach to elasticity imaging that could overcome some of the problems hindering development and clinical application of the existing approaches and could provide a shorter and easier way to realize devices for remote evaluation of elasticity and viscosity of tissues for medical applications. A further long term objective is to develop a simple, inexpensive and, possibly, hand-held ultrasonic device which in addition to the civilian health care applications of sonoelasticity, such as detection of hard lumps in breast, will facilitate specialized defense applications, e.g., diagnosis of brain trauma and edema, shrapnel detection, evaluating tissue blood supply, monitoring the healing of neuromuscular system, etc.

The main characteristic feature of the present approach is that mechanical stress needed to obtain measurable strain and evaluate elasticity is produced in a form of highly localized shear waves remotely induced by the radiation force of a focused ultrasound pulse. The frequency of shear waves (typically in the low kHz range) is adjusted such that the volume of tissue involved in this mechanical excitation is of the order of 1 cm^3.

We have theoretically estimated that the optimal choice of the parameters of an ultrasonic irradiation system enables one to induce detectable shear oscillations in soft tissues at ultrasonic exposure levels routinely used in commercial pulse Doppler or real-time B-mode and M-mode imaging devices. Model experiments made on tissue phantoms using an ultrasonic system designed for hyperthermia applications were in a qualitative agreement with the theoretical estimates. Currently, a complete theory is being developed that enables one to calculate temporal and spatial parameters of shear waves induced in a tissue with given elasticity by a known ultrasonic field. A laboratory model of the device is being designed and built.

This project is being conducted in collaboration with the Physics Department of Moscow State University, the Institute of Mathematical Problems of Biology of the Russian Academy of Sciences and the Bioengineering Program of the University of Michigan in Ann Arbor.

A. P. SARVAZYAN
Department of Chemistry, Rutgers University,
New Brunswick, NJ 08903
Phone: (908) 445-4792, Fax: (908) 445-5312
Email: sarvazyan@zodiac.rutgers.edu

I prefer an oral presentation

MEDICAL ULTRASOUND IMAGE IMRPOVEMENT OPPORTUNITIES: (1) IMPROVED BATTLEFIELD IMAGING THROUGH CORRECTION OF TISSUE INDUCED ABERRATIONS; (2) IMPROVED BREAST CANCER DETECTION THROUGH INVERSE SCATTERING.

Steven Johnson
TechniScan, Inc., 958 W LeVoy Dr.
Salt Lake City, Utah 84123

TechniScan, Inc. has developed methods for removing defocusing, blurring and excess speckle generation and other adverse effects on clinical ultrasound image quality caused by the inhomogeneous variation of tissue acoustic index of refraction. One such method is based on the inverse scattering (I.S.) approach, wherein the wave equation is solved to produce quantitative images of the inhomogeneous speed of sound, absorption and density in terms of the incident field and the measured scattered field. I.S. is particularly useful when measurement of transmitted energy through tissues is possible, such as can be the case for breast imaging. In this case, the imaging and detection of breast cancer is greatly enhanced by use of wide aperture, circumscribing transducers that contribute to an I.S. improvement of 4 to 16 times (depending on lesion depth) in spatial resolving power over present clinical methods at the same frequency.

A second method, synthetic focusing, reflectivity imaging provides 3 to 12 times improved spatial resolving power. These methods have been implemented and validated with laboratory data using test objects and tissues.

A third method, based on global cross correlation functions, has undergone limited tests using computer simulated data and gave improved performance over present "phase aberration correction methods". This method was designed to correct for 2-D refraction everywhere in the reflectivity image, and not just in a "phase shift compensation layer" next to the transducer. It also has given an independent, accurate, but low band passed filtered, 2-D image of refractive index to complement the reflective image.

Laboratory mechanical and electronic scanners have been constructed to explore 3-D and real time data acquisition for future clinical applications of these methods. The Technology is also being applied in Sonar/Mine detection.

Dr. Steven Johnson
TechniScan, Inc.
958 W LeVoy Dr.
Salt Lake City, Utah 84123
Phione: (801) 266-7700
Fax: (801) 261-1182

Oral Presentation preferred. Poster Presentation acceptable
Overhead Projector needed.

Sattelite Telemedicine

B.K. Stewart and S.J. Carter, University of Washington

Unavailable at time of printing

NET-SHAPE PIEZOCOMPOSITE TRANSDUCERS FOR ULTRASONIC IMAGING ARRAYS

L. J. BOWEN and R. L. GENTILMAN,
Materials Systems Inc.
521 Great Road, Littleton, MA 01460.

Piezoelectric ceramic/polymer composites, originally developed under ONR funding for Navy applications, have found commercial application in medical ultrasound as imaging transducers operating at megahertz frequencies. The medical transducer industry uses dice-and-fill methods for producing the very fine piezoelectric ceramic elements required in a typical imaging array. Although this manufacturing method has served the industry well for over ten years, future requirements for higher operating frequency and 2D layout will require extremely fine elements, improved control of interelement coupling and crosstalk, and advanced array designs that challenge the capabilities of dicing technology.

Under ONR and ARPA funding, Materials Systems Inc. has developed net-shape ceramic injection molding processes for cost-effectively manufacturing complex arrays of the fine PZT ceramic elements required for advanced composite transducers. Net-shape formed piezocomposites are now becoming available in commercial quantities for the first time, allowing new transducer configurations to be developed for medical ultrasound and nondestructive testing, as well as undersea imaging, surveying, sensing, and actuation.

In this presentation, Materials Systems Inc. briefly introduces its PZT injection molding manufacturing process, and then reviews the capabilities of the process for fabricating various composite transducer designs relevant to high frequency medical ultrasound. Recent information on directly producing complex composite element layouts is presented. Additional capabilities, anticipated to become commercially available within the next one to two years, include extremely fine PZT element dimensions (<25μm), high PZT volume fraction, new polymer matrix materials, improved dimensional control, large area devices, and greatly reduced cost.

The challenges involved with integrating this composite manufacturing approach into medical ultrasound systems are reviewed, and opportunities considered for applying injection molding to enhance the performance of future medical ultrasound transducer arrays.

Dr. L. J. Bowen
Materials Systems Inc.
521 Great Road
Littleton, MA 01460
Phone: (508) 486-0404
Fax: (508) 486-0706
Email:

I prefer an oral presentation, overhead projector required.

Ultrasonic Transducer/Array Research at Penn State

K. Kirk Shung, Wenwu Cao, W. Jack Hughes, Jon Meilstrup,
Tom Shrout, William Thompson, Jr. and Richard L. Tutwiler
Whitaker Center for Medical Ultrasonic Transducer Engineering
The Pennsylvania State University
University Park, PA 16802

A Center for Medical Ultrasonic Transducer Engineering has been established at the Pennsylvania State University, University Park, PA, supported by a "Biomedical Engineering Special Opportunity Award" from the Whitaker Foundation, Washington, DC and contributions from ultrasonic imaging equipment manufacturers. The missions of the Center are (1) to pursue state-of-the-art research in ultrasonic transducers and arrays for medical applications by building upon the existing strengths in ultrasonic imaging, piezoelectric materials, and sonar array technology at the University, (2) to be a center of education for training ultrasonic transducer design engineers, and (3) to serve as a technology resource for ultrasonic imaging equipment and transducer manufacturers.

There are a variety of research projects currently underway at the Center which is equipped with all necessary transducer fabrication, modeling, and testing facilities including an Optison® real-time Schlieren system, a wafer dicing saw, a Paryline coating system, and the FLEX finite element analysis software. The major research efforts include the development of linear arrays of frequencies higher than 20 MHz based on fine grain PZT and single crystal relaxor materials, finite element analysis and experimental validation of interactions among elements in arrays and piezoelectric posts in composite materials, and developments in multidimensional arrays and associated beam forming electronics. Commercial PZT which has grain size approaching element size of high frequency arrays or post size of high frequency composites is deficient in these applications whereas interactions among elements or posts severely degrade the performance of an array and should be better understood. Other multidimensional array approaches such as hexagonal array that have been used in microwave and underwater acoustics and more flexible beam forming architecture should be explored. To facilitate these endeavors, a multifunctional electronic testbed will have to be developed. Recent progress that has been made in these efforts will be reviewed and future work discussed.

K. Kirk Shung
Whitaker Center for Transducer Engineering
231 Hallowell Bldg.
The Pennsylvania State University
University Park, PA 16802
Phone: (814) 865-1407
Fax: (814) 863-0490
E-mail: KKSBIO@ENGR.PSU.EDU

I prefer an oral presentation.

SCIENCE AND TECHNOLOGY BASED DEVELOPMENTS AT NRL RELATED TO MEDICAL ULTRASONIC IMAGING

H. H. Chaskelis

Mechanics of Materials Branch

Naval Research Laboratory

Washington, DC 20375

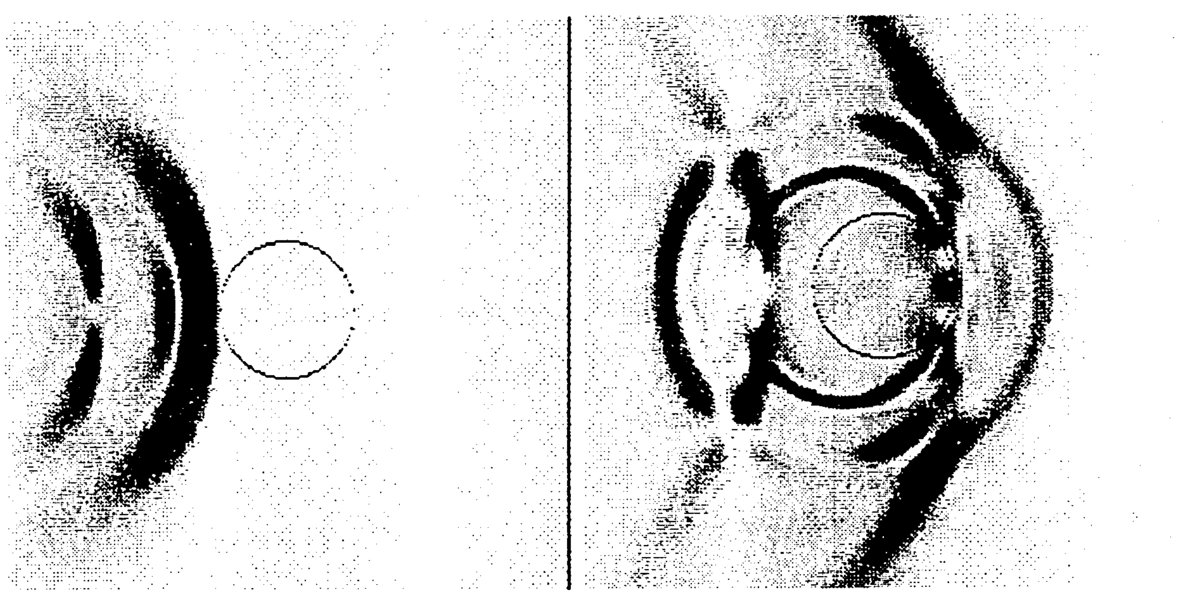
This presentation will highlight technological advances at NRL which may significantly impact the development of improved medical ultrasonic imaging capabilities. Included will be the following:

2-Dimensional acoustic wave simulator using parallel processing techniques.

Tomographic reconstruction approaches.

Transducer evaluation methods

Propagation in highly attenuative media



Simulations of acoustic waves in solid medium

Henry Chaskelis
Code 6385
Ph. (202) 767-3613
Fax. (202) 767-9181
Email. henry@ch.nrl.navy.mil
I prefer an oral presentation and will require VCR/monitor

FULL BANDWIDTH UTILIZATION WITH DIGITAL BEAMFORMING

J. E. POWERS, R. R ENTREKIN, J. SOUQUET
Advanced Technology Laboratories
PO Box 3003, Bothell, Washington 98041

Recent advances in transducer technology have greatly increased the bandwidth that can be achieved with medical imaging ultrasound transducers. Using state of the art digital ASIC technology this bandwidth, and hence information content, can be maintained through the beamformation process. These advances in technology, combined with greatly increased digital signal processing power allow novel imaging techniques not possible with previous narrow band designs. We will discuss two techniques which have only recently become feasible within commercially produced ultrasound systems.

Speckle noise is a well known artifact of medical ultrasound images which results from the coherent beamformation process. It reduces contrast resolution, makes the image more difficult to interpret, reduces the effectiveness of compression techniques, and complicates image segmentation for 3D and automated target recognition. Image processing techniques used to smooth speckle typically blur the image decreasing detail resolution. Reducing the speckle noise without reducing spatial resolution requires averaging independent estimates of tissue backscatter at every location. This can be accomplished by acquiring the image using multiple independent frequency bands to provide uncorrelated backscatter estimates, and averaging the results.

Conversely, ultrasound bandwidth can also be used to eliminate the signal from tissue which complicates blood flow detection in moving organs. Recently developed ultrasound contrast agents consist of tiny stabilized air bubbles which resonate at typical medical imaging frequencies. At resonance, these bubbles become nonlinear, producing harmonics and subharmonics of the interrogating frequency. This gives the agent a signature allowing it to be distinguished from the surrounding tissue by a characteristic other than velocity, the signature used by Doppler and color flow techniques. By transmitting at one frequency and receiving at twice that frequency, signal to clutter increases of 15-20 dB have been demonstrated.

These new developments in medical ultrasound point the way to a new generation of products with capabilities not possible with previous, narrowband processing. These might include adaptive beamforming, automated measurements, and tissue characterization.

Jeff Powers, Ph.D.
ATL, MS 265
PO Box 3003
Bothell, WA., 98041-3003
Phone: (206) 487-7126
Fax: (206) 486-5220
Email: jpower@atl.com
I prefer an oral presentation requiring a slide projector.

HIGH-SPEED, LOW-POWER SIGNAL PROCESSORS FOR PORTABLE MEDICAL ULTRASOUND

Alice M. Chiang

TeraTech Corporation
223A Middlesex Turnpike, Burlington, MA 01803

Medical ultrasound, or ultrasonography, is a safe, effective and widely used diagnostic imaging modality. However, even state-of-the-art high-end phased-array ultrasound systems are based on a twenty-year old design to which only incremental improvements have been made. Systems are expensive, heavy, necessitating transport on a cart, and more importantly, image quality is well below what is theoretically possible. The opportunity exists for making significant advances in ultrasound technology, both in terms of improving image quality, providing flow imaging with better Doppler resolution and in reducing size, power consumption and cost of hardware. Furthermore, a portable, low-power, high-resolution ultrasound can be used to improve care to trauma cases such as a wounded soldier on battlefield or an injury at remote location. Future enhancements to the portable system can be videocompression of the images, so the diagnostic information obtained by the emergence medical professionals can be linked through wireless digital communication to the control center for decision support.

The need for high-throughput signal processors in an ultrasound is ubiquitous. For example, a large number of delay-and-sum circuits are needed for dynamic beamforming, a pulsed-Doppler processor is needed for providing range-and-Doppler information in a flow imaging, a bank of finite-impulse-response filters are needed to provide spatial interpolation for better range resolution, a 2-D transformation device is needed for spatial domain compression and a motion-estimation processor for time-domain compression. Each of these emerging applications needs a processor capable of more than 10,000 million operations/s (MOPs). A major hardware challenge for these applications is the development of processors capable of massive computations while being of sufficiently low-power consumption and small size to be embedded in a portable system. It is well known that conventional digital implementation offers flexibility and unlimited accuracy. However the state-of-the-art DSPs only offer several hundred MOPs/chip and each chip requires a few watts of electric power. Thus an ultrasound with conventional digital signal processors would still require hundreds of chips and hundreds of watts. This talk will describe a charge-domain processing, CDP, technology that combines high-speed, low-power analog charge-domain units with conventional CMOS digital control and memory circuits to create a new type of electronics -- chips capable of tremendous computation power while being of low power consumption and small chip area.

The shift-and-delay attributes offered by the charge-domain device are inherently matched to the time-delay function needed for dynamic focusing in a lensless ultrasound. To demonstrate further the computation power offered by this CDP technology, a single-chip Pulsed-Doppler Processor with a frequency interpolation capability, an adaptive filter implementing both an FIR filter and an LMS adaptive algorithm and an videocompression coder will also be described. A 25,000 MOPs/W performance has been demonstrated by this technology. Only when this type low-cost, low-power, high-throughput processors is utilized, a portable, high-resolution ultrasound image system will then be feasible.

DIGITAL TECHNOLOGY FOR MEDICAL ULTRASOUND IMAGING

Michael N. Witlin and Michael E. Haran
Manassas Laboratory, Loral Federal Systems
9500 Godwin Drive, Manassas, VA 22110

We have been developing and delivering U.S. Navy digital sonar systems since the early 1970's. Recently, we delivered a digital system based on Commercial-Off-The-Shelf (COTS) technology and a custom 0.5 micron VLSI product. We believe that this VLSI technology coupled with other COTS products can be used to significantly enhance medical ultrasound imaging. A single multi-chip package of these VLSI chip sets operating at 50 MHz provides 600 million operations per second. This technology provides beamformation with range dependent focusing and apodization of sensor data from arrays at a performance level not yet employed in existing medical systems. The processing capacities provided by a single 19 inch rack of electronics of our latest COTS based system will be used as an illustration. A requirement for the digital beamforming capacity for a future medical ultrasound system will be derived based on a two dimensional sparse sensor array. It will be used to illustrate a sizing procedure to determine the number of multi-chip packages required to process the sensor information in real time and the resulting resolution and field of view generated.

Michael E. Haran, Senior Systems Engineer
Manassas Laboratory, Loral Federal Systems
9500 Godwin Drive
Manassas, VA 22110
Phone: (703) 367-1397
Fax: (703) 367-6319
Email: haran@lfs.loral.com

I prefer an oral presentation.
My presentation requires an overhead projector.